NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER
P.O. BOX 271
LA JOLLA, CA 92038

SOUTHWEST FISHERIES CENTER
LIBRARY
JUN 28 1990
National Marine Fisheries Service
2570 Dole Street
Honolulu, Hawaii

AUGUST 1989

# EFFECTS OF DOLPHIN GROUP TYPE, PERCENT COVERAGE, AND FLEET SIZE ON ESTIMATES OF DOLPHIN MORTALITY DERIVED FROM TUNA VESSEL OBSERVER DATA

By

Elizabeth F. Edwards and Christina Perrin

ADMINISTRATIVE REPORT LJ-89-22

This Administrative Report is issued as an informal document to ensure prompt dissemination of preliminary results, interim reports and special studies. We recommend that it not be abstracted or cited.

# EFFECTS OF **DOLPHIN GROUP TYPE, PERCENT COVERAGE,** AND **FLEET SIZE** ON ESTIMATES OF DOLPHIN MORTALITY DERIVED FROM TUNA VESSEL OBSERVER DATA.

by

Elizabeth F. Edwards
and
Christina Perrin

Southwest Fisheries Center/NMFS
P.O. Box 271
La Jolla, CA 92038

ADMINISTRATIVE REPORT LJ-89-22

TABLE OF CONTENTS


| | Page |
|---|---|
| ABSTRACT | 1 |
| INTRODUCTION | 2 |
| METHODS | 3 |
| Data | 3 |
| Simulations | 4 |
| RESULTS | 10 |
| General Characteristics of 1987 Data Set | 10 |
| Within-Year Estimates | 11 |
| Annual (Small Fleet) Estimates | 12 |
| DISCUSSION | 13 |
| Dissimilarities | 13 |
| Patterns in Sample Characteristics | 16 |
| IMPLICATIONS | 20 |
| Sample Characteristics and Variance Estimation | 20 |
| Fleet Size | 22 |
| Sampling Levels | 22 |
| CONCLUSIONS | 23 |
| ACKNOWLEDGEMENTS | 24 |
| LITERATURE CITED | 25 |


LIST OF TABLES


| | | Page |
|---|---|---|
| Table 1. | Observed annual mortality and number of trips incurring mortality for 8 groups of dolphins killed during fishing by U.S.-registered tuna purse-seine vessels carrying observers in the eastern tropical Pacific during 1987 | 26 |
| Table 2. | Relative bias and coefficients of variation for estimates of total annual mortality of dolphins derived from simulations allowing (a) or not allowing (na) sampling of consecutive cruises. Sampling coverage was 50%, fleet size was 33 boats | 27 |

TABLE OF CONTENTS (continued)

LIST OF FIGURES


| | | Page |
|---|---|---|
| Figure 1. | Sampling protocol for small-fleet simulations..... | 28 |
| Figure 2. | Number of observed U. S. registered tuna purse-seine vessels at sea, and number of observed vessels leaving port each month during 1987..... | 30 |
| Figure 3. | Frequency distribution of months spent at sea per trip by U. S. registered tuna purse-seine vessels carrying observers during 1987..... | 32 |
| Figure 4. | Frequency distribution of kill/trip during fishing by observed U.S. registered tuna purse-seiners during 1987 for a) northern offshore spotter dolphins, b) whitebelly spinner dolphins, and c) common dolphins..... | 34 |
| Figure 5. | Estimated and observed cumulative kill of dolphins by U.S. registered tuna purse-seine vessels fishing in the eastern tropical Pacific Ocean during 1987. Estimates are derived from samples of 25%, 33, 50%, 75% and 96% of observed trips. Individual panels show results for a) total dolphins, b) northen offshore spotted dolphins, c) eastern spinner dolphins, d) whitebelly spinner dolphins, e) common dolphins, f) unidentified spinner dolphins, g) striped dolphins, and h) other dolphins..... | 36 |
| Figure 6. | Relative bias in estimated cumulative kill of dolphins by U.S. registered tuna purse-seine vessels fishing in the eastern tropical Pacific Ocean during 1987. Estimates are derived from samples of 25%, 33, 50%, 75% and 96% of observed trips. Individual panels show results for a) total dolphins, b) northern offshore spotted dolphins, c) eastern spinner dolphins, d) whitebelly spinner dolphins, e) common dolphins, f) unidentified spinner dolphins, g) striped dolphins, and h) other dolphins..... | 38 |

LIST OF FIGURES

Page

Figure 7. Coefficient of variation for estimated cumulative kill of dolphins by U.S. registered tuna purse-seine vessels fishing in the eastern tropical Pacific Ocean during 1987. Estimates are derived from samples of 25%, 33, 50%, 75% and 96% of observed trips. Individual panels show results for a) total dolphins, b) northern offshore spotted dolphins, c) eastern spinner dolphins, d) whitebelly spinner dolphins, e) common dolphins, f) unidentified spinner dolphins, g) striped dolphins, and h) other dolphins..... 40

Figure 8. Relative bias in estimates of annual dolphin mortality as a function of fleet size. RBs are presented for 3 dolphin groups (northern offshore spotted, whitebelly spinner, and common dolphins), 4 sizes of fleet (5, 10, 20, and 33 boats) and 3 levels of observer coverage (25, 50, and 75%). Each column shows the average relative bias for a given condition of dolphin, fleet size, and percent coverage. Each set of 3 columns shows results for a particular fleet size. The first 4 sets of columns show results for 25% coverage, the next 4 sets show results for 50% coverage, and the last 4 sets show results for 75% coverage..... 42

Figure 9. Coefficients of variation for estimates of annual dolphin mortality as a function of fleet size. CVs are presented for 3 dolphin groups (northern offshore spotted, whitebelly spinner, and common dolphins), 4 sizes of fleet (5, 10, 20, and 33 boats) and 3 levels of observer coverage (25, 50, and 75%). Each column shows the average relative bias from 10 replicate simulations for a given condition of dolphin, fleet size, and percent coverage. Each set of 3 columns shows results for a particular fleet size. The first 4 sets of columns show results for 25% coverage, the next 4 sets show results for 50% coverage, and the last 4 sets show results for 75% coverage..... 44

TABLE OF CONTENTS (continued)

LIST OF FIGURES


Page

Figure 10. Frequency distributions of estimated annual mortality of dolphins incurred by the observed 33-boat U.S. tuna purse-seine fleet during 1987, given 25% or 50% coverage..... 46

Figure 11. Frequency distributions of estimated annual mortality of northern offshore spotted dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage..... 48

Figure 12. Frequency distributions of estimated annual mortality of whitebelly spinner dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage..... 50

Figure 13. Frequency distributions of estimated annual mortality of common dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage..... 52

Figure 14. Confidence intervals ($\hat{K} \pm 2$ standard errors) for estimated annual mortality of dolphins incurred by the observed 33-boat U.S. tuna purse-seine fleet during 1987, given 25% or 50% coverage..... 54

Figure 15. Confidence intervals ($\hat{K} \pm 2$ standard errors) for estimated annual mortality of offshore spotted dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage..... 56

Figure 16. Confidence intervals ($\hat{K} \pm 2$ standard errors) for estimated annual mortality of whitebelly spinner dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage..... 58

Figure 17. Confidence intervals for estimated annual mortality of common dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage..... 60


LIST OF APPENDICES


Page

Appendix I. Tabled results from within year mortality simulations..... 62

Appendix II. Tabled results from small-fleet (annual) mortality simulations..... 71

## ABSTRACT

Records of dolphins killed incidental to purse-seining for tuna by U.S. registered vessels fishing in the eastern tropical Pacific Ocean during 1987, were analyzed to assess the effects of three factors (1) dolphin group, 2) percent coverage (percent of fishing trips observed by scientific technicians), and 3) fleet size) on estimates of dolphin mortality incurred by an entire fleet, when only a portion of the fishing trips made by a fleet is actually observed. Data from 1987 were used because this is the first year that nearly 100% of trips carried observers.

Estimates were derived using the ratio estimator (kill/day) for eight dolphin groups (total dolphins, offshore spotted dolphins, eastern spinner dolphins, whitebelly spinner dolphins, unidentified spinner dolphins, common dolphins, striped dolphins, and other dolphins). Estimates of cumulative monthly mortality of each dolphin group for the entire fleet of 33 boats were calculated for simulated sampling levels of 25%, 33%, 50%, 75%, and 96% observer coverage. Estimates of total annual mortality of each dolphin group were estimated for simulated fleet sizes of 5, 10 and 20 boats sampled at simulated coverages of 25%, 50%, and 75%.

Four statistical aspects of these mortality estimates were investigated to assess the effects of the three factors named above, on the estimates. These aspects included 1) relative bias of the estimate, 2) coefficient of variation of the estimate, 3) frequency distributions of replicate estimates, and 4) 95% confidence intervals of replicate estimates.

Mortality estimates and their statistical (sampling) characteristics were affected in decreasing order of influence by dolphin group type, percent coverage, and fleet size.

The strongest control on mortality estimates was the sampling characteristics of the data contributing to the estimates. For groups with relatively frequent and relatively similar kill/trip (e.g., total dolphins), a given level of accuracy and precision could be achieved with relatively low percent coverage even with relatively small fleets. The same level of accuracy and precision (e.g., relative bias less than about 5%, coefficient of variation less than about 20%) could be achieved at intermediate levels of coverage for dolphin groups with intermediate data characteristics (e.g., whitebelly spinner dolphins, with relatively infrequent but relatively homogeneous kill/trip). But for dolphin groups with relatively rare and heterogenous kill/trip (e.g., common dolphins), much higher levels of coverage are required to achieve this level of accuracy and precision, and the level increases with smaller fleets.

As specific examples, CVs 20% or less could be achieved for estimates of total annual mortality given 25% coverage of a fleet of 20 boats, or 50% coverage of a fleet as small as 5 boats. CVs of 20% or less for whitebelly spinner dolphins required coverages of at least 75% for a fleet of 5 boats, and at least 50% for fleets of 20 boats. CVs of 20% or less could not be achieved for estimates of common dolphin annual mortality even with coverages as high as 96%, at any fleet size.

Because neither fleet size nor dolphin group type can be controlled by a sampling program, the only alternative available to achieve given levels of accuracy and precision in estimates of dolphin mortality is to manipulate the level of observer coverage. To protect equally all groups, it will be necessary to use the level required for those dolphin groups characterized by the least abundant and most unevenly distributed data.

## INTRODUCTION

Observers on tuna vessels fishing in the eastern tropical Pacific Ocean record the numbers of dolphins killed during purse-seine fishing for dolphin-associated tuna, in order to estimate total mortality and mortality of individual stocks of dolphins. Both fleet size (number of vessels) and percent observer coverage (percentage of vessels carrying observers) can be expected to affect these mortality estimates. Although the issue has not been addressed specifically in the past, differences in data characteristics between dolphin groups (stocks, species, or the aggregate data set) may also affect estimates.

This study uses data collected from U.S. purse-seine vessels during 1987 to investigate the effect of these three factors (dolphin group type, percent coverage, and fleet size) on two types of mortality estimate: 1) estimates of <u>within-year cumulative mortality</u>, and 2) estimates of <u>annual mortality</u>. Data from 1987 were used because this is the first year that almost 100% of trips by U.S. purse-seiners carried observers (124 observed of 133 trips by 33 vessels, from a total of 134 trips made by 34 U.S. vessels during 1987).

Estimates of <u>within-year</u> cumulative mortality were investigated because this estimate is required by U.S. law to monitor the approach of dolphin mortality to annual quotas for the U.S. fishery. Estimates of <u>annual</u> mortality were investigated because estimated mortality rates will be used in future (1989 and subsequently) to determine whether tuna caught "on dolphin" by non-U.S. countries may be imported into the United States.

Effects of dolphin group type and percent coverage are investigated both for within-year and for annual estimates of mortality. Effects of fleet size are investigated only for

estimates of annual mortality, for two reasons: 1) within-year estimates are required only for the U.S. fleet, which has not changed in size in 3 years (34 vessels during each of 1987, 1988, and 1989), and 2) with the exception of Mexico (41, 50 and 48 vessels in 1987, 1988, and 1989), non-U.S. fleets tend to be much smaller than the U.S. fleet. For example, during 1987, Venezuela had 25 vessels, Panama and Vanuatu 5 each, Ecuador 4, and Spain 1.

Two sets of simulation results are presented here, pertaining to the two types of mortality estimate. The first set of simulations investigated the effects of 5 different percent coverages (25, 33, 50, 75, and 96% of observed trips on U.S. vessels during 1987) on estimates of cumulative with-in year mortality of all dolphins and of 7 species/stocks of dolphins. Number of vessels (33) was not varied in this first set of simulations. The second set of simulations investigated the effect of 3 different fleet sizes (5, 15 or 20 vessels) and 3 levels of coverage (25, 50, and 75% of observed trips) on estimates of annual mortality of all dolphins and annual mortality of 3 species/stocks of dolphins (offshore spotted dolphins, eastern spinner dolphins, and common dolphins; the three stocks whose abundance is most significant in current quotas).

Four statistical aspects of these mortality estimates were investigated to assess the effects of the three factors named above, on the estimates: 1) relative bias of the estimate, 2) coefficient of variation of the estimate, 3) frequency distributions of replicate estimates, and 4) 95% confidence intervals of replicate estimates.

Relative bias expresses the accuracy of the estimate (how close one is to the true number), coefficient of variation expresses the precision of the estimate (how variable a series of estimates might be), frequency distributions show the sampling distribution of the estimate (specifically, is it normally distributed), and replicate confidence intervals show how often the results derived from each estimation process actually encompasses the true value (i.e, do all estimates have about the same degree of "fuzziness"). Taken together, these four factors present a relatively complete picture of the likelihood that an estimate based on any given sample, such as the single sample available per year from which annual estimates of mortality must be derived, will be reasonably close to the truth.

## METHODS

### Data

During 1987, 34 U. S.-registered purse seine vessels carrying certificates permitting fishing "on dolphin" made a total of 134 fishing trips to the eastern tropical Pacific Ocean (ETP). Of these trips, 124 were observed by either a National Marine Fisheries (NMFS) or an Inter-American Tropical Tuna Commission (IATTC) technician. These 124 observed trips comprise the entire population

for this study; they accounted for 93% of all trips and 96% of all days spent at sea in the ETP by U.S.-registered tuna purse-seiners during 1987.

The primary data set consisted of a file containing one record per day spent at sea for each of the observed trips. This sampling unit of one day was chosen because the ratio estimate used here to estimate cumulative within-year dolphin mortality is **kill per observed day**. Multiplying this ratio estimate by the total number of fleet days (both observed and unobserved) produces the estimate of mortality for the whole fleet (during both observed and unobserved trips).

Each data record included as variables: cruise number (scrambled for IATTC-observed trips), date, position, and totals for that date. These totals included: number of sets on dolphins, tons of tuna caught (total tuna and yellowfin tuna) and observed mortality of 8 groups of dolphins. These groups included offshore spotted dolphins (northern and southern combined), whitebelly spinner dolphins, eastern spinner dolphins, common dolphins, striped dolphins, "unknown" (unidentified spinner) dolphins, "other" dolphins, and all (total) dolphins. Estimates derived during this simulation study used data from this primary data set and other summary files derived from it.

We have assumed in these studies that all trips can be considered replicates, i.e., fishing effort was the same on all vessels. Although it has been suggested that mortality rates may differ between observed and unobserved cruises (Wahlen and Smith 1985, Croom 1980), no firm evidence yet exists to either affirm or refute this assumption. In the absence of quantitative evidence to the contrary, we assume here that this effect is negligible.

## Simulations

Within-Year Estimates. Simulations generating within-year estimates of mortality on U.S. vessels were conducted at sampling coverages of 25%, 33%, 50%, 75% and 96% of the total population of 124 trips. Each sampling was replicated 1000 times. Each replicate at each sampling level was an independent sample of trips selected randomly and without replacement, producing 1000 mortality estimates. Each cumulative mortality estimate reported here is the average of these 1000 replicate mortality estimates; CVs and RBs are characteristics of these average estimates.

The mortality estimates reported for these within-year estimates are based on a ratio estimate of kill/day. We chose this estimate rather than kill/set or kill/tons-tuna-caught, because the purpose of this set of simulations was to determine the effect on estimates of within-year cumulative kill of varying the percent coverage of the fleet, using the methodology currently practiced by

NMFS for within-year monitoring of dolphin mortality (e.g., Lo et al. 1982).

Estimates derived in this first set of simulations are cumulative kill by the entire fleet, for each of the 8 groups estimated at monthly intervals. Thus estimates for January report kills accumulated through January 31, estimates for February report kills accumulated from January 1 through February 28, estimates for March report kills accumulated from January 1 through March 31, and so forth. Monthly accumulation simulates reasonably well the bi-weekly reporting of within-year cumulative estimates by NMFS, but reduces by half the computer time that would be required for bi-weekly simulations. Annual mortality is of course cumulative mortality through 31 December.

Because relevant fleet characteristics (e.g., number of vessels actively fishing (Figure 1), duration of trips (Figure 2) and kill of individual stocks) varied with time, each replicate subsample at each level of percent coverage (P%) was generated by selecting randomly without replacement within each month and independently between months, P% of the trips which departed in each month. Once a trip has been selected, that trip remains selected throughout all the months of its duration. This procedure preserves the temporal structure of the data set.

For example, 20 trips departed in January, 7 departed in February. Thus for a 25% subsample, 20*0.25 or 5 trips were selected randomly from the 20 departing in January. For months such as February when the sampling percentage results in a fractional number of trips to be selected from trips departing that month (e.g., 7*0.25 = 1.75), the number of trips selected for each replication was rounded randomly up or down to the nearest integer as a function of the fraction, so that in the long run the number of cruises selected for a month approached the appropriate number for the specified percent coverage (e.g., 1.75 for 25% coverage in February, producing a cumulative total of trips through February of 5 (from January) + 1.75 (on average from February) = 6.75).

Within each replicate(L), cumulative kill estimates for each dolphin group(I), month(J) and percent coverage(k) were calculated as the ratio estimate

$$\hat{Y}(I,J,K,L) = (K(I,J,K,L)/DAYS(J,K,L))*TFDAYS(J)$$

where $\hat{Y}(I,J,K,L)$ is the estimated cumulative kill of dolphin group(I) through month(J) at percent coverage(K), K(I,J,K,L) is the total observed kill of dolphin group (I) during all sampled trips through month(J) at percent coverage(K), DAYS(J,K,L) is the number of observed days during all sampled trips through month(J) at percent coverage(K). TFDAYS(J) is the total number of days fished by the entire fleet through month(J) (i.e., the population number of fleet days).

Average within-year mortality estimates were calculated as

$$YAVE(I,J,K) = (1/1000) * \sum_{L=1}^{1000} \hat{Y}(I,J,K,L)$$

where YAVE(I,J,K) is the average of the 1000 replicates samples(L) of dolphin group(I) through month(J) at percent coverage(K).

Relative bias of each YAVE(I,J,K) was calculated as

$$RB(I,J,K) = [YAVE(I,J,K) - \text{known kill}(I,J)]/[\text{known kill}(I,J)]$$

where RB(I,J,K) is the relative differences between the average of the 1000 replicate estimates of mortality for dolphin group(I) through month(J) at percent coverage(K), and the known kill of dolphin group(I) through month(J).

Coefficient of variation for each YAVE(I,J,K) was calculated as

$$CV(I,J,K) = [\sqrt{MSE(YAVE(I,J,K))}]/[\text{known kill}(I,J)]*100$$

where $\sqrt{MSE(YAVE(I,J,K))}$ is the mean squared error of the average of the 1000 replicate estimates of mortality for dolphin group(I) through month(J) at percent coverage(K), calculated as

$$MSE(YAVE(I,J,K)) = V(YAVE(I,J,K)) + [YB(I,J,K)]^2$$

where YB(I,J,K) is the absolute bias of the average mortality estimate, calculated as

$$YB(I,J,K) = YAVE(I,J,K) - \text{known kill}(I,J)$$

and V(YAVE(I,J,K) is the variance of the 1000 replicate samples of mortality for dolphin group(I) through month(J) at percent coverage(K) and is calculated as

$$V(YAVE(I,J,K) = (1/999) * \sum_{L=1}^{1000} (\hat{Y}(I,J,K,L) - YAVE(I,J,K))^2$$

Annual Estimates (Small fleet Simulations). For the small-fleet simulations, we first selected 5, 10, or 20 boats from the total of 33 observed boats. We then sampled 25%, 50%, or 75% of the trips made by each of these selected vessels. Thus the small-fleet simulations involve a preliminary stage of sampling (selecting a subset of the total of 33 observed vessels) not conducted in the simulations for the U.S. fleet (Figure 1).

Because the data from so few boats are so sparse, we did not force temporal stratification on these small fleet simulations. Samples of trips were selected randomly and without replacement from

the trips made by the selected vessels, without regard to timing of those trips.

Selections of vessels were replicated 10 times at each combination of fleet size and percent coverage. Selection of trips from each set of selected vessels was replicated 50 times. Thus, selected vessels were the same within each set of 50 replicate samples of trips, but differed between sets of 50 replicates. Trips and boats were selected randomly and without replacement. The trips conducted by the selected vessels in each sample fleet represent the "population" of trips for that fleet replicate.

Each set of 50 replicate selections of trips from a given set of selected vessels generated 50 estimates of cumulative mortality through December. For each set of 50 estimates, we calculated the mean estimate, and then the coefficient of variation (CV), and the relative bias (RB) of this mean estimate. Thus for each combination of fleet size and percent coverage we generated 10 averaged estimates of annual mortality, 10 coefficients of variation, and 10 estimates of relative bias. As an example, Appendix II shows 10 lines of data describing the mean estimate of the 50 replicates taken within each fleet size and percent coverage, with a final line showing the average estimate, the average CV, and the average RB for these 10 estimates, for the cumulative annual estimate of mortality of total dolphins given a fleet size of 10 vessels sampled at 50%.

Because the "true" kill varied from fleet replicate to fleet replicate depending on the particular vessels selected, the average of the 10 resulting averaged (from the 50 replicates) estimates of cumulative mortality is not a particularly useful measure in this study. This average represents only the average of the 10 sets of vessels that happened to be chosen for the 10 replicates of fleet size. However, the coefficients of variation and estimates of relative bias for each of the 10 averaged estimates are relevant indicators of the ability of the estimation process to accurately and precisely reflect the true kill, whatever it happens to be for a particular sample of vessels. Thus we present results for the small-fleet simulations only for the averages of the 10 estimates of CV and RB generated for each of the 9 combinations of percent coverage and fleet size. We do not discuss directly the actual mortality estimates.

To maintain comparability between the results for the within-year simulations and these annual (small fleet) simulations, we used the same ratio estimator (Kill/day) in both sets of simulations.

Dolphin mortality data were not stratified geographically, despite the demonstrated efficiency of this stratification scheme (e.g., Hall and Boyer 1986) because it can be applied only when data sets are large enough to provide reasonable numbers of data per

stratum. Attaining sufficient data per stratum would have been a problem for the less frequently killed dolphin groups in the 1987 data set (e.g., whitebelly spinner and common dolphins) and is likely to be a problem for small fleets in every year. Because real world data from small fleets will usually be too few to employ geographic stratification, we chose here to assume this worst case of insufficient data for stratifying by area.

In contrast to the simulations for within-year estimates of mortality, which presented results for 8 groups of dolphins, results are presented and discussed in detail only for 3 dolphin groups in the small fleet simulations. These groups are offshore spotted, whitebelly spinner, and common dolphins. We chose to focus discussion on these 3 groups because they encompass the range of effects caused by variations in characteristics of the kill data from which the mortality estimates are derived. For completeness of the record, exact results are presented in Appendix II for these three groups of dolphins, in addition to results for total dolphins and for eastern spinner dolphins.

We do not discuss results for the dolphin groups eastern spinner, striped, unidentified spinner, and "other" because mortality of these groups was relatively low, and the general effects of fleet size and percent coverage on estimates from small data sets are illustrated here by the results for whitebelly spinner and common dolphins. We do not discuss results for total dolphins because the characteristics and implications from offshore spotted dolphins apply equally to the total, because this stock comprises the majority of the total kill of all dolphins.

Average estimated mortality, relative bias, and coefficient of variation were calculated in the same way for these annual (small-fleet) estimates as for the within-year estimates, except that: 1) we calculated only cumulative mortality through December, so the identifier for individual months(J) is deleted and 2) sampling and replicating fleet sizes requires two new identifiers, one for fleet size and one for fleet size replicate.

Percent Coverage: Estimates and Statistics. The identifiers for the annual (small fleet) simulations are dolphin group(I, I = 1,2,3; offshore spotted, whitebelly spinner, and common dolphin), fleet size(J, J = 1,2,3; for 5, 10, 20 boats), fleet replicate(K, K = 1,..,10), percent coverage(L, L = 1,2,3; for 25%, 50%, and 75%) and percent coverage replicate(M, M = 1,...,50).

For each of the 50 replicates(M) of a given percent coverage(L), within a given fleet replicate(K) at a given fleet size(J), the annual mortality estimate ($\hat{Y}$) for a given group of dolphins(I) is calculated as the ratio estimate

$$\hat{Y}(i,j,k,l,m) = (K(I,J,K,L,M)/DAYS(J,K,L,M)) * TFDAYS(J,K)$$

where K(I,J,K,L,M) is the observed annual kill and DAYS(J,K,L,M) is the observed number of days during trips conducted by vessels in fleet replicate(K) at fleet size(J), sampled at percent coverage(L) within coverage replicate(M). TFDAYS is the total number of days spent at sea by all the vessels selected in replicate(K) of fleet size(J).

For each set of 50 replicate estimates of annual mortality at a given percent coverage, we calculated the average estimate (YAVEC), its relative bias (RBYC), and its coefficient of variation (CVYC) as follows

$$YAVEC(I,J,K,L) = (1/50) * \sum_{M=1}^{50} \hat{Y}(I,J,K,L,M)$$

$$RBYC(I,J,K,L) = 100 * \frac{[YAVEC(I,J,K,L) - known\ kill(I,J,K)]}{known\ kill(I,J,K)}$$

where known kill(I,J,K) is the total known kill of dolphin group(I) during trips selected from fleet replicate(K) at fleet size(J).

$$CVYC(I,J,K,L) = [\sqrt{MSE(YAVEC(I,J,K,L))}]/known\ kill(I,J,K,L)]*100$$

where

$$\sqrt{MSE(YAVEC(I,J,K,L))} = V(YAVEC(I,J,K,L)) + [BYAVEC(I,J,K,L)]^2,$$

$$BYAVEC(I,J,K,L) = YAVEC(I,J,K,L) - known\ kill(I,J,K)$$

where BYAVEC is the absolute bias of YAVEC, and V(YAVEC(I,J,K,L)) is the variance of YAVEC, calculated as

$$V[YAVEC(I,J,K,L)] = (1/49) * \sum_{M=1}^{50} (\hat{Y}(I,J,K,L,M) - YAVE(I,J,K,L))^2$$

The preceding equations produce 10 average estimates of mortality, 10 relative biases of those averages, and 10 coefficients of variation, for each combination of fleet size and percent coverage.

Average estimates of relative bias (RBYF) and coefficient of variation (CVYF) were calculated for each dolphin group(I) at each combination of fleet size(J) and percent coverage(L), as

$$RBYF(I,J,K) = (1/10) * \sum_{K=1}^{10} ABS(RBYC(I,J,K,L))$$

where ABS() indicates absolute value
and

$$CVYF(I,J,K) = (1/10) * \sum_{K=1}^{10} CVYC(I,J,K,L) \ .$$

## Patterns in sample characteristics

The mortality estimates investigated here are the means of either 1000 (within-year estimates) or 500 (10x50; small fleet estimates) replicates. Confidence intervals (CIs), relative bias (RB) and coefficients of variation (CVs) for the within-year estimates were derived from the 1000 replicates at each percent coverage. Confidence intervals, relative bias and coefficients of variation for the small fleet simulations were derived from the 10 replicate mortality estimates at each combination of fleet size and percent coverage. In both cases, CIs, RBs and CVs were derived from the bootstrapped replicates.

Because confidence intervals, relative bias and coefficients of variation for the small-fleet simulations were calculated from only 10 estimates of mortality (although each of the 10 RBs and CVs were derived from 50 replicate simulations within each combination of fleet size and percent coverage), and because we had no evidence either supporting or refuting the assumption of normality in mortality estimate distributions for either the within-year or annual mortality estimates, we plotted both frequency distributions and analytic 95% confidence intervals for several of the replicate individual mortality estimates, both within-year and annual. Frequency distributions show the sampling distributions of mortality estimates under each set of conditions. Plots of analytic confidence intervals for individual replicates indicate whether any consistent pattern exists (e.g., with increasing size of the estimate) that might explain observed results or indicate unanticipated problems. The analytic confidence intervals are as calculated by the IMSL routine SMPRR for ratio estimates (IMSL 1987). This routine calculates confidence intervals for ratio estimates using the analytic formula for approximate variance of a ratio. The procedure is based on the assumption that a normal approximation to the ratio variance is appropriate (Cochran 1977, IMSL 1987).

We present here representative examples from several of the combinations, to indicate changes in patterns of estimate characteristics with changes in dolphin group type, percent coverage, and fleet size.

For the within-year estimates, we plotted results only for the cases of 25 and 50% coverage, as these lower levels of observer coverage are the most likely to generate biased and variable (poor) estimates given a fleet size as large as 33 boats.

For the annual estimates we plotted results for the cases of 5 and 20 boats at 25 and 75% coverage, assuming that we might observe problems even with coverages as high as 75% with fleet sizes as low as 20 (or worse, 5) boats.

Results for both sets of estimates are presented only for the three dolphin groups (offshore spotted, whitebelly spinner, and common) chosen to illustrate the three patterns of dolphin kill data, progressively deteriorating in efficacy for mortality estimation.

## RESULTS

### General Characteristics of 1987 Data Set

Kill data for offshore spotted dolphins (Figure 4a) were both relatively frequent (116 out of 124 trips incurred dolphin mortality) and are relatively smoothly distributed (most trips killed 50-100 dolphins; high kills occurred on only a small fraction of remaining trips; the decrease in frequency of kill/trip from 50-100 dolphins/trip to several hundred per trip was relatively smooth). Kill data for whitebellys (Figure 4b) were less frequent (62 out of 124 trips) but still relatively smoothly distributed (most trips killed about 10 dolphins; decreasing frequency of kill/trip was relatively smooth). Kill data for common dolphins were neither frequent nor smoothly decreasing. Mortality of common dolphins (Figure 4c) was observed on only 12 of 124 trips, and of those 12 trips, kill/trip was less than 20 animals on two-thirds of the trips (8/12), but was 34, 55, 137, and 594 on the remaining four trips.

The number of observed vessels at sea during each month remained fairly constant at about 30 throughout the year (Figure 2). The number of vessels departing during each month fluctuated from 20 to 5, with the only general pattern being a decrease from March through September (Figure 1). About 50% of the trips were 3 months duration; trips of 2 or 4 months duration comprised another 20% each of the trips (Figure 2). Numbers of trips incurring mortality of each type of dolphin (i.e., number of sampling units for each group) ranged from 116 (total dolphins) to 8 (striped) dolphins (Table 1).

Patterns in kill/trip were similar for most dolphin groups. Kill/trip was low or zero during most trips, with roughly exponentially decreasing numbers of trips having increasingly high kills (Figure 4). The smoothest decreases occurred in groups with both the highest and most frequent kills (e.g., total dolphins, offshore spotted dolphins. Decreases were least smooth for the groups with less frequent and lower kills (e.g., common dolphins).

## Within-Year Estimates

Tables of results appear in Appendix I. Figures depicting results are discussed below.

Cumulative within-year mortality estimates (Figure 5). Total mortality increased relatively steadily during the year (Figure 5a). This increase was driven primarily by mortality of offshore spotted dolphins, which comprised much of the total throughout the year (Figure 5b). Mortality of offshore spotters increased from 40% of the total kill accumulated during January to 63% of the total accumulated through December. Eastern spinner dolphin (Figure 4c) was the only other identifiable stock which accumulated relatively heavy mortality in the beginning of the year. However, in contrast to the case for offshore spotters, kill of eastern spinner dolphins decreased relative to the total with time, from about 30% of the total mortality through April to about 18% through December. The number of deaths in the other 3 identifiable groups (whitebelly spinner dolphins, common dolphins, and striped dolphins) tended to increase more rapidly during the latter half of 1987 than during the first half. Mortality of these 3 groups and the 2 groups of non-specified dolphins ("unidentified spinner dolphins" and "other") was considerably lower than the mortality throughout the year for offshore spotters and eastern spinners.

The averaged estimates of cumulative monthly mortality were in all cases very accurate and quite insensitive to percent coverage, improving only slightly with increasing percent coverage (Figure 5). This was true of abundant as well as relatively rare groups (e.g., offshore spotters vs. "unknown").

Relative bias. As indicated by the close overlap between lines in the graphs of cumulative mortality (Figure 5), relative bias tended to be small (less than about 5%) for all estimates at all percent coverages (Figure 6).

Relative bias was lowest and least variable for groups with the largest kills (total, offshore spotters, and eastern spinners). Relative bias was more variable for the groups with relatively low mortality, both within months at different percent coverages and as mortality accumulated during progressive months (e.g., common dolphin, Figure 6).

Coefficients of variation. As with the cumulative estimates, CVs for total mortality primarily reflect patterns in CVs for offshore spotted dolphins and eastern spinner dolphins because these 2 groups comprise the majority of the kill and thus the majority of the sub-sampled kill (Figure 7). CVs tended to be higher and more variable for groups with low cumulative mortality (e.g., striped dolphins, common dolphins, others, and unknowns).

CVs decreased consistently and strongly with increasing percent coverage for all groups during each month. CVs also tended to decrease through the year as kill accumulated, but these within-year decreases were neither smooth nor consistent for most groups. Within each group, patterns of change month-to-month in CVs were identical at all 5 percent coverages, but pattern amplitudes decreased progressively with increasing coverage, being most pronounced for 25% coverage and least pronounced at 96% coverage. For example, CVs for spotted dolphins were about 35% at 25% coverage, about 20% at 50% coverage, and about 5% at 96% coverage. (Figure 7).

## Annual (Small Fleet) Estimates

Tables of results appear in Appendix II. Figures depicting results are discussed below.

Cumulative annual estimates. The average of the mortality estimates themselves are not reported directly here, as the ability of the estimator to mirror the true kill is expressed by the relative bias. The actual level of kill within any replicate is unimportant to the present study, which addresses general questions about variance and the procedure's ability to estimate with little or no bias, given different fleet sizes and percent coverage.

Relative Bias. In general, the average relative bias decreased with increasing percent coverage and increasing mortality within any fleet size (Figure 8). Relative bias tended to be insensitive to fleet size, changing neither markedly nor consistently with increases in fleet size from 5 to 20 boats. Relative bias was quite low (less than 5%) for all fleet sizes and all groups other than common dolphins, at percent coverages 50% or greater, and at 25% coverage for the larger fleet sizes (20 and 33 vessels). Relative bias for common dolphins was consistently much higher than bias of the other groups, particularly at low percent coverage (25%), reflecting the combination of few and heterogeneously distributed data characterizing mortality records for common dolphin during 1987.

Coefficient of variation. Coefficients of variation decreased both with increasing fleet size and with (as was the case for the within-year estimates) increasing percent coverage in the more abundant and evenly distributed groups (e.g., offshore spotters, Figure 9). In the group with both infrequent and very uneven kill/trip (e.g.,

common dolphins), the coefficient of variation of the mortality estimate decreased with increasing percent coverage, but not dramatically or consistently with fleet size within any given percent coverage.

## DISCUSSION

These two simulation experiments were performed to provide a basis for decisions concerning sampling levels required for both the U.S. and non-U.S. fleets. Sufficient sampling coverage is required for the U.S. fleet in order to determine within-year approach by the U.S. fleet to the various quotas for dolphin mortality. Sufficient sampling coverage is required for the non-U.S. fleets to determine whether each fleet wishing to export tuna to the U.S. has satisfied the requirements of the amended MMPA. Although the simulations were designed to mirror as accurately as possible the sampling procedures and characteristics of data collected by tuna vessel observers, there are several differences between these simulations and the ideal, the ideal being defined as data satisfying completely all statistical assumptions and requirements for mortality estimation, sampled in the simulations in a manner identical to the sampling procedure in actual practice, and collected directly and without artifact for the fleet(s) in question.

In the following section we discuss the apparent importance of three potentially significant differences between our simulations and the ideal case - 1) for the within-year estimates of mortality for the U.S. fleet, our simulations permitted sampling of consecutive cruises, contrary to the usual sampling procedure, 2) the small fleet simulations present results from U.S. vessels, but the results are to be applied to the non-U.S. fleet, and 3) we did not stratify the data by geographic area or flag (nationality).

Following this discussion of dissimilarities between our study and the "real world", we discuss implications for mortality estimates, of sample characteristics (frequency distributions and confidence intervals) resulting from our simulation studies.

### Dissimilarities

Consecutive Cruises. In practice in the past (prior to the 1989 ruling requiring 100% coverage of U.S. vessels), NMFS placed observers on every other trip made by each vessel, based on a sampling schedule determined several years ago at the inception of the sampling program, and continued to the present (John Young, pers. comm)[1]. As vessels tend to make several consecutive trips

---

[1]John Young, Tuna Porpoise Management Branch, Field Office, Southwest REgion, 1520 State Street, Suite 200, San DIego, CA 92101-2983.

throughout a year, this sampling schedule tends to spread the sampling effort more or less evenly throughout the year, although at any one time slightly more or less than 50% of the vessels at sea may be carrying observers.

In order to maintain desired sampling levels other than 50% in the within-year simulation experiments, a given percentage of departing cruises were selected from each month's set of departing cruises. Under this scheme consecutive cruises might be selected for individual vessels. To test the effect that this difference in sampling protocol might have on within-year mortality estimates, we conducted a set of simulations at a sampling level of 50%, then estimated cumulative total mortality of dolphins and compared relative bias and coefficients of variation derived from these forced non-consecutive cruises, with estimates from the defined percentage per month method.

Results were almost identical for both RB and CV in both sets of simulations (Table 2), leading us to conclude that implications from the defined percentage method would not be changed materially by re-running the remainder of the simulations with the forced non-consecutive method.

U.S. vs. Non-U.S. data. The relevance of our results from this sampling of a data set from the U.S. fleet, for recommending levels of coverage on non-US fleets, depends on the assumption that all fleets fish similarly in space, time and methodology. This is not strictly true, as some fleets tend to concentrate in some areas more than others, thus fishing more heavily on the species most common in these targeted areas.

While the effects of varying fleet size and percent coverage of non-U.S. fleets ideally would be addressed with data from non-U.S. vessels, these data have not been made available because by international agreement, data for individual nations other than the U.S. are not released by the agency responsible for collecting those data (the Inter-American Tropical Tuna Commission, IATTC). There is conflicting evidence about the existence and significance of differences between U.S. and non-U.S. data.

Comparisons of mortality estimates and variances for U.S. vessels (as one group) vs. non-U.S. vessels (all non-U.S. fleets combined into a second group) showed little difference between the estimates (Hall and Boyer 1986, Hall 1989[2]). For example, estimates of total annual mortality of dolphins due to fishing by the

---

[2]Martin Hall, Incidental Mortality of Dolphins in the eastern tropical Pacific Tuna Fishery, 1979-1988, Working Document #2, Tuna-Dolphin Workshop, San Jose, Costa Rica, March 14-16, 1989; sponsored by Inter-American Tropical Tuna Commission, c/o Scripps Institution of Oceanography, La Jolla, CA, 92093, U.S.A.

international fleet, where data were stratified by flag as either U.S. or non-U.S., were 1.5% (kill/set on dolphins) and 2.5% (kill/ton yellowfin caught during dolphin sets) higher than estimates unstratified by flag during 1986 and 1987. Variances of the estimates averaged 6% (Kill/set) and 7% (Kill/ton) higher. Given the suite of uncertainties associated with these data, these differences are not large.

However, geographic differences confounded with differences in areas of concentrated effort by U.S. vs. non-U.S. vessels may be generating as-yet undetermined differences between mortality estimates of different nations. For example, the Mexican purse-seine fleet concentrates on common dolphin schools relatively near shore within Mexico's EEZ; this effort is not matched anywhere by a similar concentration of U.S. vessels, because U.S. vessels are barred from Mexico's EEZ, and common dolphins are abundant primarily in this area rather than further offshore where U.S. vessels concentrate their effort.

But, in support of the similarity between U.S. and non-U.S. data, it is also true that while some specifics in fishing effort may differ between the data set used here and a truly non-US data set, the general procedures and gear involved in purse-seining for tuna associated with dolphin schools tends to be similar between nations, regardless of the area fished, lending credence to the general conclusions presented here with regard to the interaction between the pattern of kill rates, fleet sizes, and percent coverages. Effects due to these three factors may outweigh differences between nations. It remains at present impossible with available data to resolve this issue.

Stratification. We did not stratify the mortality data by geographic area or nation. These strata have been used by other researchers to derive estimates of mortality from TVOD and have been shown to have some advantages in reducing bias, and especially variability, in the resulting mortality estimates (e.g., Hall and Boyer 1986). In the case of the U.S. fleet (within-year) simulations, these procedures were not used because we wanted to simulate the estimation process as it is now practiced. In the case of the small-fleet simulations, we did not follow those procedures because we wanted the results from both sets of simulations to be comparable, and because a review of available data implied to us that our conclusions would not be changed materially by stratifying the data.

We did not feel that our results would be changed materially for the following reasons. Hall and Boyer (1986) and Hall(1989, Working paper #2) have shown that stratification by geographic area reduces variance in estimates of mortality for the international fleet based on kill/set and kill/ton but does not report results for the U.S. fleet alone, nor for kill/day. Thus our results are not strictly comparable to these other estimates.

However, based on Hall's results, stratifying by geographic area would probably have reduced in our simulations the CVs for mortality estimates of abundant groups of dolphins (by reducing with-in strata heterogeneity in the mortality estimates) and perhaps improved the relative bias of the less abundant groups (by preventing extrapolation of estimates to areas where less abundant groups may not occur; e.g., common dolphins far offshore). But alternatively, stratification reduces the number of data points available for estimates within any strata, increasing the influence of outliers and thus inflating CVs of the less abundant groups. In any case, relative bias in the cumulative estimate through December (ie, in annual estimates) tended to be quite low for all groups despite the lack of geographic stratification (ie, no great improvement would be expected by stratifying), and patterns in CV reduction with increasing fleet sizes and percent coverages would not be expected to change greatly under stratification, although the quantitative details might.

Frequency Distributions. Within-Year Estimates. For simulations based on the entire 33-boat U.S. fleet, frequency distributions of replicate estimates of mortality for groups with relatively smoothly distributed kill/trip were distributed relatively normally even at 25% coverage (e.g., offshore dolphins, Figure 10). This was true even for groups killed relatively infrequently (e.g., whitebelly spinner dolphins, Figure 10). Some skewness is evident in all these distributions, but it is not consistently either positive or negative. Tests for skewness would undoubtedly show significant departure from strict normality, but the skewness in these three groups is not extreme.

The situation is markedly different for the dolphin group with infrequent mortality distributed heterogeneously among trips (e.g., common dolphins, Figure 10). Here, two distinct modes in the frequency distribution of mortality estimates are apparent. The modes are particularly apparent at 25% coverage, but even at 50% coverage they are still quite noticeable. These figures make obvious the reason for the high bias and variance found in this group's estimates of mortality; the combination of relatively low kill distributed very unevenly among relatively few cruises causes the pathological degradation of estimates. That the problem is not due simply to low mortality (few kills) is indicated by the results for the whitebelly spinner dolphins. Commons and whitebellys had roughly comparable kills during 1987 (commons, 882 observed deaths; whitebellys, 981; Figure 4) but the statistics for whitebellys are much less biased and variable because individual data points are both more abundant and more homogeneously distributed for this group. This is because the basic sampling unit is a trip. During 1987, whitebelly mortality was observed on 62 trips, while mortality of common dolphins was observed on only 12 trips.

Annual Estimates (Small Fleet Simulations). Frequency distributions of small fleet estimates were affected least by replicate number,

somewhat more by fleet size, noticeably by percent coverage, and very strongly by dolphin group type (Figures 11, 12, and 13). These are the same general patterns as seen in the within-year estimates, but with bias and variability exacerbated due to small sample sizes and heterogeneous data within samples.

Fleet size of course affected the modal values of frequency distributions, being larger for larger fleets (which of course generally kill more dolphins). But at low percent coverage, changes in fleet size had little effect on dispersion of the frequency distributions. Dispersion was as great for 20 boat fleets as for 5 boat fleets, sampled at 25%.

Increasing percent coverage affected frequency distributions by generating narrower and more peaked (i.e, more normally distributed) sets of estimates at 75% than at 25% coverage for all three groups of dolphins and both fleet sizes, although the effect was less for dolphin groups with inherently high variability (common dolphins, Figure 13). These effects result of course from the increasing similarity in data sets selected for each set of replicates, as percent coverage increases (at 100% coverage, each replicate would contain exactly the same data set).

Dolphin group type, or more specifically, the patterns in data resulting from a dolphin group's kill records exerted an even stronger effect than percent coverage on frequency distributions. Comparing frequency distributions of replicate mortality estimates from different groups of dolphins illustrates dramatically the degeneration in sampling distribution that occurs as the underlying data set becomes more scarce and more variable. Frequency distributions of estimates for annual mortality of offshore spotted dolphins tended to be relatively tight for fleets of both 5 and 20 vessels, at 75% coverage (Figure 11). Distributions for whitebelly dolphins were similar but somewhat more dispersed, especially with lower percent coverage and larger fleet size (Figure 12), but distributions for common dolphins are markedly bi-modal under all sampling conditions, as a result of this group's small and heterogenous data set (Figure 13).

Confidence Intervals. Because patterns in confidence intervals were quite similar from one set of 50 replicates to the next, within any one set of 10 runs at a given fleet size and percent coverage, only one example is presented for each condition of dolphin group type, percent coverage, and fleet size.

Within-Year Estimates. With a fleet as large as 33 boats, 95% confidence intervals are relatively smooth and uniform in width for groups with relatively frequent and/or homogeneous mortality even at coverages as low as 25% (e.g., offshore spotted dolphins, whitebelly spinner dolphins, Figure 14). There is a tendency for confidence intervals to increase with increasing size of the mortality estimate but this effect is generally small.

As with the frequency distributions of estimates, however, patterns are exaggerated dramatically for common dolphins, again because of the infrequent and uneven nature of the kill data for this groups during 1987 (Figure 14). About one-quarter of the samples at 25% failed to detect any mortality of common dolphin at all, generating of course confidence intervals of zero. Over 56% of the confidence intervals were below the true value; these estimates tended to have narrow confidence limits because only the trips with smaller kills had been selected. The remaining 44% of the confidence interval included the true mortality. Of this 44%, about half were characterized by very wide confidence intervals, because these estimates were derived from replicate samples that chose fortuitously the one or two trips that had much higher kills (e.g., 594 during 1 trip, compared to only 10-20 animals during most other trips; Figure 3). The effect of increasing percent coverage to 75% was in this case simply to increase the percentage of 95% confidence intervals that included the true kill, from 46% to 60%. Thus, for common dolphins, the simulated confidence level of 95% confidence interval was only 46% at 25% coverage, and 60% at 75% coverage.

Annual (small fleet) Estimates. The 95% confidence intervals for the small fleet simulations again show the progressively important effects of fleet size, percent coverage, and dolphin group type on the sampling characteristics of the mortality estimates. Differences between plots result, as was the case for the frequency distributions, primarily from characteristic differences between dolphin groups in the amount and variability of data collected for each group.

The effects of limited and heterogeneous data, both alone and in combination, can be seen clearly in the steady degeneration of confidence interval homogeneity with decreasing sample sizes and with increasing heterogeneity. Estimates are most stable and confidence intervals most homogeneous for offshore spotted dolphins sampled at 75% from a fleet of 20 vessels (Figure 15). These "best" estimates result from the most abundant and homogeneous data set. Confidence intervals become progressively less even as the amount of data collected decreases, the "worst" set of estimates occurring under for the smallest fleet (5 boats) and lowest percent coverage (25%). At this lowest level of percent coverage and fleet size, even the estimates for offshore spotters become noticeably ragged (Figure 15). This is not surprising, of course, as this combination of fleet size and percent coverage means that the mortality estimates are being derived from about 4 observed trips during an entire year (assuming 5 boats make 3 trips/year, 15 trips x 0.25 = 4).

For the group with relatively scarce but relatively homogeneous data (whitebelly dolphins, Figure 16), confidence intervals are again relatively homogeneous and estimates relatively invariant for the case where the most data were collected (20 boats, 75% coverage). But the estimates and intervals for this group

degenerate faster with decreasing data collection than was the case for total dolphins because the effects of fortuitously selecting unusually high or low values are relatively more severe.

Confidence intervals were the least homogenous for the groups with the fewest and most heterogeneous data (common dolphins, Figure 17). For this group, confidence intervals were strongly heterogenous even at the highest level of data collection (20 vessels, 75% coverage), because so few trips incurred mortality of these dolphins, and because variability in mortality/trip was so high.

## IMPLICATIONS

### Sample Characteristics and Variance Estimation

The importance of relative bias, coefficient of variation, frequency distributions and confidence intervals for estimates of dolphin mortality is that these four descriptors each provide indications of the probability that one additional sample (i.e., the one sample we get each year from the fishery, which forms the basis for the annual mortality estimate) will provide an estimate that is acceptably close to the truth for the entire fleet. Low bias and variability, strongly peaked sampling distributions, and confidence intervals of uniformly homogeneous width all imply that the next sample is likely to provide an estimate close in value to the true kill, and to most previous estimates. A primary advantage of observing these desirable patterns in a data set is that standard analytical formulae for variances can be used in the estimation process. Unfortunately, we tend to find these patterns in the dolphin mortality estimates only for the more abundant groups, at higher percent coverages, in relatively large fleets.

Bootstrapping is a potentially appropriate alternative method for deriving estimates and variances (e.g., Hall and Boyer 1986), with the significant advantage of not relying on any assumptions about the distribution of the estimated statistic.
Unfortunately, bootstrapping <u>does</u> depend heavily on the assumption that the characteristics of the sample are representative of the characteristics of the population from which the sample was drawn, i.e., that the proportions of items in the sample that have various values are the same as the proportions of the items in the population with similar values. For example, a representative sample of a population in which 20% of the items have values exceeding X would itself have 20% of the sampled items with values exceeding X.

For dolphin groups with relatively similar levels of mortality per trip and relatively frequent trips incurring mortality, any sample of trips is likely to be reasonably representative of mortality throughout the whole fleet even if the number of trips with observed mortality is small (e.g., total dolphins, offshore

dolphins, whitebelly spinner dolphins). Given these frequent and similar kill/trip data, most samples will produce about the same estimate and estimated variance (e.g., offshore spotted dolphins, Figure 15). Of course, the likelihood of achieving a representative sample increases with increasing percent coverage, until at 100% coverage the representative sample converges with the population itself.

But for dolphin groups with heterogenous mortality data, especially those with few observed trips incurring mortality, the likelihood is much smaller that any given sample will be truly representative of mortality throughout the whole fleet (e.g., common dolphin). Unfortunately, it is impossible to tell from a single sample exactly how unlikely it is.

The 1987 data set for common dolphins is a good example of the type of data that are problematic not only for analytic variance estimation, but for bootstrapped estimates, as well. This data set incorporates both characteristics that seem to degrade significantly mortality estimates; frequency of kill was low, but variability in the number killed per observation was quite high. These problems exemplify an unfortunate interaction between data collection problems and the ecology of the dolphins themselves. Kills of common dolphins by the U.S. fleet during 1987 were infrequent because the geographic range of this species is relatively limited and occurs primarily within Mexico's EEZ (Exclusive Economic Zone). U.S. vessels rarely fish in this area. Kills are variable due at least in part to this species unfortunate habit of forming very large schools, thus pre-disposing them to the possibility of very large-kill "disaster" sets.

The uneven structure of this data set for common dolphins has unfortunate implications for deriving bootstrap estimates of mortality for dolphin groups that are characterized by having infrequent and widely variable kill/trip. Estimates of mortality will vary widely depending on which trips happen to be chosen. In our simulation, we had the advantage of being able to re-sample the total population of vessels repeatedly, thus generating relative unbiased, though individually variable, estimates of mortality. In the real world, we get only one sample per year. If this sample is collected under low percent coverage, we are very likely to have collected an undetectably biased sample, and the bias is more likely to underestimate than overestimate mortality, as kills are not only infrequent, but tend to be small when they do occur. The problem with missing the large-kill sets is that the kill in these sets can apparently be one or two orders of magnitude greater than the "usual" kill. For very abundant groups, missing a few large kills will still mean missing only a small percentage of the total population; for less abundant groups, the large kills represent a larger proportion of the standing stock. Thus a combination of fishing economics and dolphin ecology conspires to make with-year estimates of mortality for this particular group problematic.

## Fleet Size

The implication of these results for sampling and estimating mortality of small fleets is that inter-vessel variability in kill/trip can have a much stronger effect on mortality estimates from small fleets than similar variability might have on estimates from larger fleets. This is because estimates derived from observing trips by a small fleet will obviously be based on few data; observing only a percentage of those trips will reduce the available data even further. Each data point will thus represent a relatively large fraction of the total data set, so the influence of outliers will be large.

By implication, our ability to estimate annual mortality accurately and precisely is affected less by the size of the fleet *per se* than by the observer coverage given the fleet, and the fleet's variability in kill/trip. Kill/trip is affected not only by the fishermen's choices of fishing methods and areas, but apparently also by the type of dolphin targeted. Because these are not factors that can be controlled, accurate and precise estimates of dolphin mortality in smaller fleets necessarily depend on higher levels of observer coverage than required of larger fleets.

## Sampling Levels

Results presented here show that in general, sampling levels required to achieve a given level of confidence in mortality estimates for any given group of dolphins are a function of (at least) group type, percent coverage, and fleet size - with no simple answer appropriate for all groups. Coverages required to achieve a given level of precision and accuracy for one group will be complete overkill for another. For example, given a fleet of 5 boats, and kill data as statistically degenerate as seen for common dolphins in the U.S data from 1987, nearly 100% coverage would be required to reduce CVs of mortality estimates for this group to less than 20%. With 33 boats, this CV could be achieved with 75% coverage (Figure 9). But at the same time, CVs of less than 20% can be achieved for the estimates of total mortality for a 5-boat fleet with coverages as low as 75%, and a 33 boat fleet, as low as 25%.

Of the three affective factors discussed here (dolphin group type, percent coverage, and fleet size), only percent coverage can be controlled by the sampling program. Fleet size is controlled by the economics of individual countries, and all data for all groups are collected simultaneously. Choosing maximum protection for all groups would require mandating coverage to achieve a desired level of statistical precision for the least statistically stable group, thereby devoting unnecessary coverage to the less aberrant groups. In the case of the 1987 data set for dolphin kill by the U.S. fleet, this would translate to coverage greater than 96% (the highest observed) for all boats in order to generate mortality estimates for common dolphins with CVs less than 20%. Alternatively, if only the

most abundant groups are considered (e.g., total dolphins, and offshore spotted dolphins), the same level of precision could be achieved at levels of 50% for fleets as small as 5 boats. There appears to be no unique solution that is optimal for all groups.

## CONCLUSIONS

If the data collected by observers from the U.S. fleet during 1987 are representative of unobserved conditions throughout the entire international fleet during that year, and subsequently, then the following recommendations can be made.

Sampling characteristics of dolphin kill data used to estimate dolphin mortality in the eastern tropical Pacific Ocean are affected by, in decreasing order of importance, 1) dolphin group type, 2) percent coverage, and 3) fleet size. This hierarchy of effects is controlled by two signal characteristics of the kill data for each type of dolphin group: 1) the frequency of trips that incur mortality, and 2) the similarity (or not) in the level of kill/trip when kills are observed.

Frequency distributions and confidence intervals of replicate estimates indicate that in order to achieve roughly the same sampling characteristics (i.e., sampling distribution and estimate homogeneity), observer coverage will need to be higher on small fleets than on large fleets.

For bootstrapped estimates, given levels of accuracy and precision might be achieved with lower coverages but only if the observed samples are truly representative samples of kill/trip for the entire fleet. The results presented here indicate simply that for the abundant groups of dolphins this may not be too difficult to achieve at lower coverages. But for the problematic groups, high coverages will still be required, in order to ensure that the samples collected are truly representative.

As neither fleet size nor type of dolphin killed can be controlled by the observer program, the only solution to achieve equal levels of precision and accuracy of mortality estimates for all dolphin groups incurring mortality appears to be using the percent coverage level required by the "messiest" data.

ACKNOWLEDGEMENTS

The U.S. fleet simulation study was designed by Bruce Wahlen. Programming for both sets of simulations was developed by Christina Perrin. Nancy Lo provided insightful advice about sampling procedures and statistical methods. We thank also the participants in the Workshop on Estimating Dolphin Mortality, who provided many useful comments during the review sessions.

## Literature Cited

Cochran, W. G. 1977. Sampling Techniques. 3rd ed., John Wiley and Sons, New York, 428 p.

Croom, M. 1980. The tuna porpoise problem: management aspects of a fishery, M.S. Thesis, Oregon State University. 41pp.

Hall, M. and S. Boyer. 1986. Incidental mortality of dolphins in the eastern tropical Pacific tuna fishery description of a new method and estimation of 1984 mortality. Rep. Int. Whal. Comm. 36: 375-381.

IMSL. 1987. SMPRR/DSMPRR. pp. 751-758, IN: IMSL, Inc. Stat. Library, International Mathematical and Statistical Library of Computer Programs.

Lo, N. C H., J. E. Powers, and B. E. Wahlen. 1982. Estimating and monitoring incidental dolphin mortality in the eastern tropical Pacific tuna purse seine fishery. Fish. Bull. 80:396-400.

Wahlen, B.E. and T. D. Smith. 1985. Observer effect on incidental dolphin mortality in the eastern tropical Pacific tuna fishery. Fish. Bull. 83(4):521-530.

Table 1. Observed annual mortality and number of trips incurring mortality for 8 groups of dolphins killed during fishing by U.S.-registered tuna purse-seine vessels carrying observers in the eastern tropical Pacific during 1987.

| Dolphin Group | Total Annual Mortality | # Trips Incurring Mortality |
|---|---|---|
| Total dolphins | 13390 | 116 |
| offshore spotted dolphins | 8437 | 93 |
| eastern spinner dolphins | 2557 | 76 |
| whitebelly spinner dolphins | 981 | 62 |
| common dolphins | 882 | 12 |
| striped dolphins | 8 | 4 |
| unidentified spinner dolphins | 55 | 13 |
| other dolphins | 470 | 45 |

Table 2. Relative bias and coefficients of variation for estimates of total annual mortality of dolphins derived from simulations allowing (a) or not allowing (na) sampling of consecutive cruises. Sampling coverage was 50%, fleet size was 33 boats. Values are percentages.

| | Relative Bias | | Coefficient of Variation | |
|---|---|---|---|---|
| | (a) | (na) | (a) | (na) |
| JAN | -1.33 | -0.85 | 52.72 | 52.90 |
| FEB | 0.49 | -0.09 | 28.76 | 29.77 |
| MAR | 0.28 | 0.06 | 22.77 | 23.22 |
| APR | 0.44 | 0.15 | 20.08 | 20.35 |
| MAY | 1.17 | 0.60 | 17.87 | 18.70 |
| JUNE | 0.98 | 0.33 | 16.11 | 17.26 |
| JULY | 0.83 | 0.45 | 13.95 | 15.49 |
| AUG | 0.57 | 0.47 | 12.06 | 13.61 |
| SEPT | 0.52 | 0.45 | 10.52 | 12.25 |
| OCT | 0.31 | 0.34 | 11.53 | 11.83 |
| NOV | 0.03 | 0.26 | 10.29 | 11.32 |
| DEC | -0.01 | 0.32 | 9.90 | 10.86 |

Figure 1. Sampling protocol for small fleet simulations.

# Sample Design

[ TOTAL FLEET = 33 BOATS ]

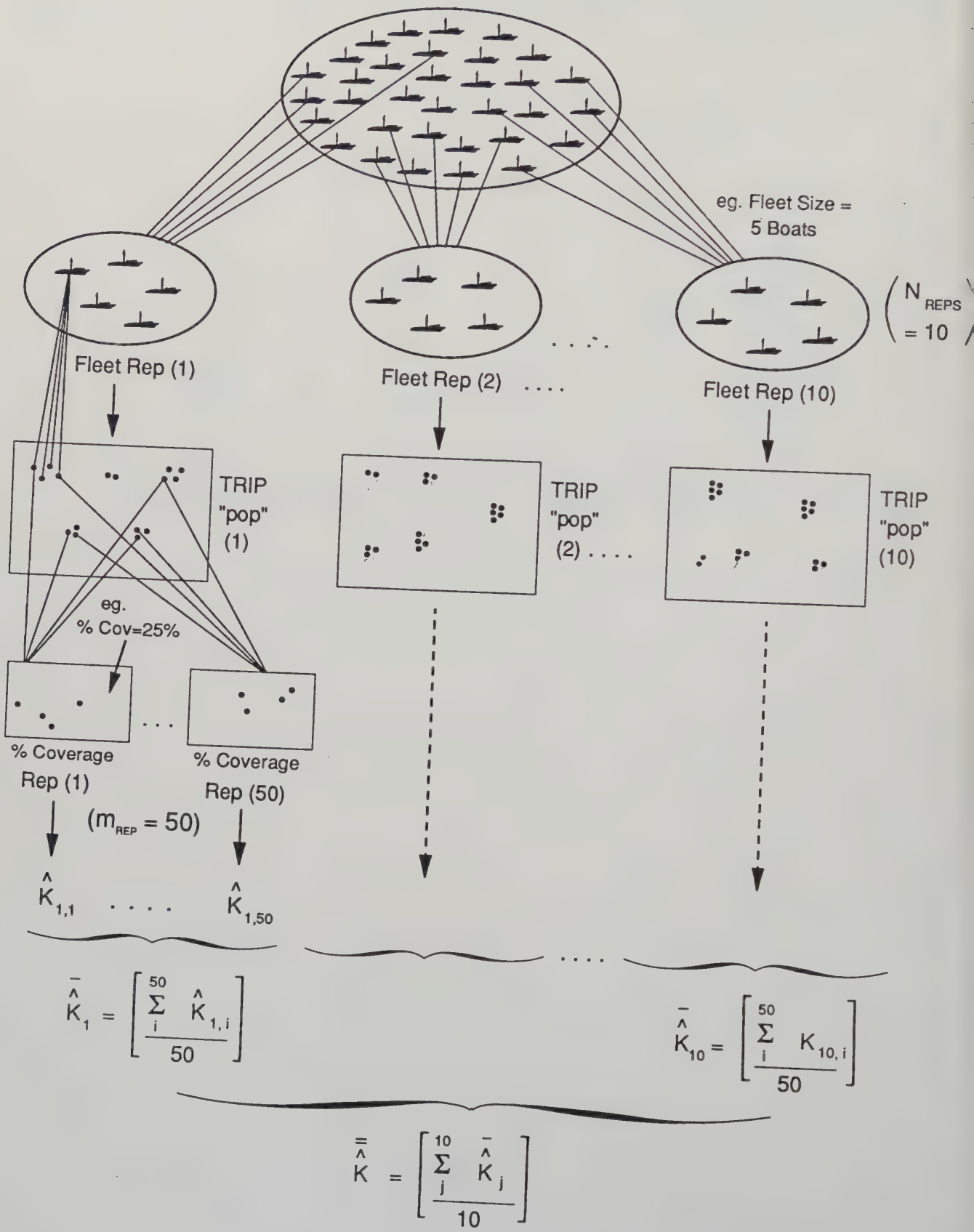

eg. Fleet Size = 5 Boats
$N_{REPS} = 10$
Fleet Rep (1)
Fleet Rep (2) . . . .
Fleet Rep (10)
TRIP "pop" (1)
TRIP "pop" (2) . . . .
TRIP "pop" (10)
eg. % Cov=25%
% Coverage Rep (1)
% Coverage Rep (50)
$(m_{REP} = 50)$
$\hat{K}_{1,1}$ . . . . $\hat{K}_{1,50}$
. . . .
$\bar{\hat{K}}_1 = \left[ \frac{\sum_i^{50} \hat{K}_{1,i}}{50} \right]$
$\bar{\hat{K}}_{10} = \left[ \frac{\sum_i^{50} K_{10,i}}{50} \right]$
$\bar{\bar{\hat{K}}} = \left[ \frac{\sum_j^{10} \bar{\hat{K}}_j}{10} \right]$

Figure 2. Number of observed U.S. registered tuna purse-seine vessels at sea, and number of observed vessels leaving port each month during 1987.

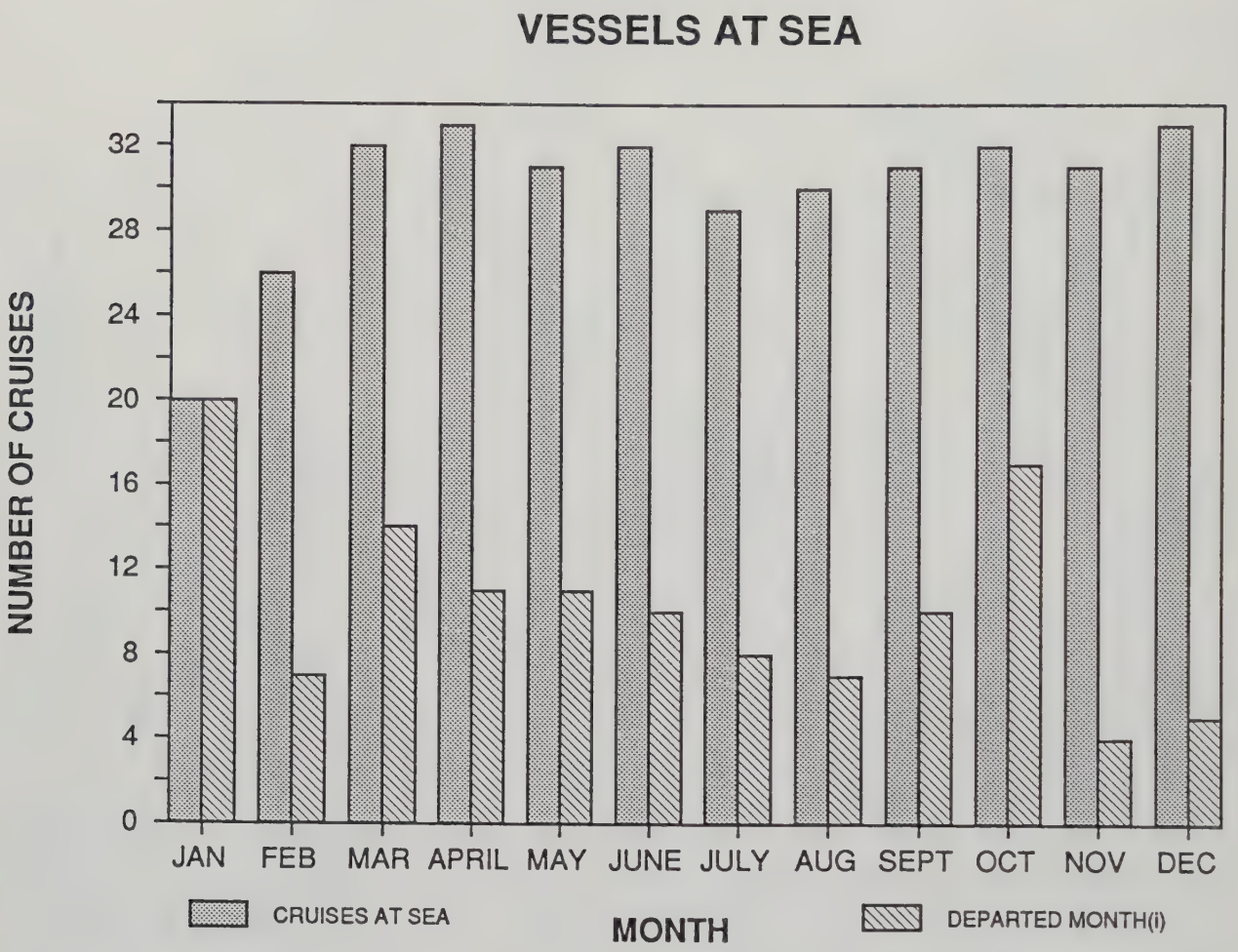

VESSELS AT SEA
NUMBER OF CRUISES
0
4
8
12
16
20
24
28
32
JAN
FEB
MAR
APRIL
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
CRUISES AT SEA
MONTH
DEPARTED MONTH(i)

Figure 3. Frequency distribution of months spent at sea per trip by U.S. registered tuna purse-seine vessels carrying observers during 1987.

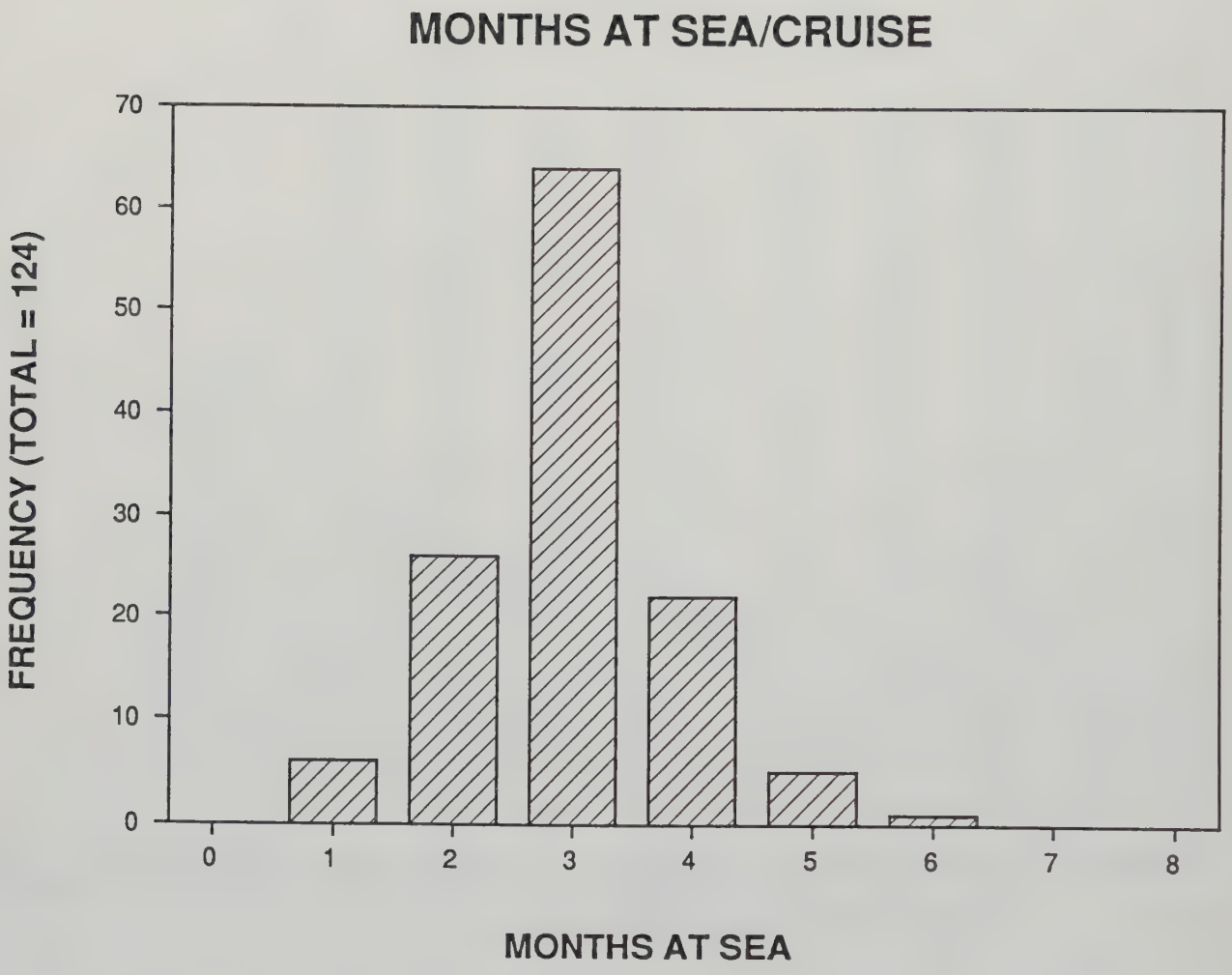

MONTHS AT SEA/CRUISE
FREQUENCY (TOTAL = 124)
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
MONTHS AT SEA

Figure 4. Frequency distribution of kill/trip during fishing by observed U.S. registered tuna purse-seiners during 1987 for a) northern offshore spotter dolphins, b) whitebelly spinner dolphins, and c) common dolphins.

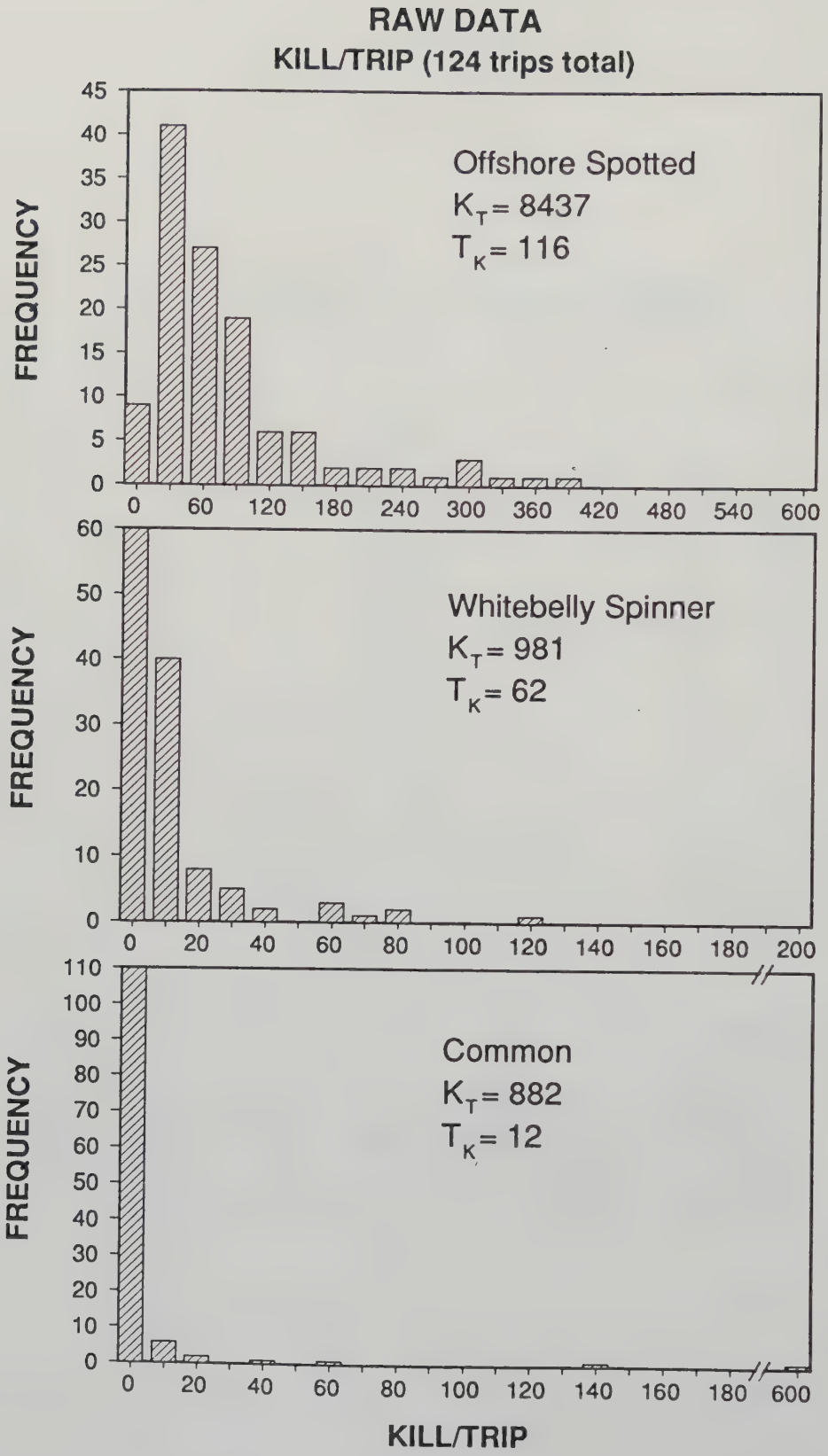

RAW DATA
KILL/TRIP (124 trips total)
FREQUENCY
Offshore Spotted
$K_T$= 8437
$T_K$= 116
0 60 120 180 240 300 360 420 480 540 600
Whitebelly Spinner
$K_T$= 981
$T_K$= 62
0 20 40 60 80 100 120 140 160 180 200
Common
$K_T$= 882
$T_K$= 12
0 20 40 60 80 100 120 140 160 180 600
KILL/TRIP

Figure 5. Estimated and observed cumulative kill of dolphins by U.S. registered tuna purse-seine vessels fishing in the eastern tropical Pacific Ocean during 1987. Estimates are derived from samples of 25%, 33, 50%, 75% and 96% of observed trips. Individual panels show results for a) total dolphins, b) northen offshore spotted dolphins, c) eastern spinner dolphins, d) whitebelly spinner dolphins, e) common dolphins, f) unidentified spinner dolphins, g) striped dolphins, and h) other dolphins.

# Cumulative Kill

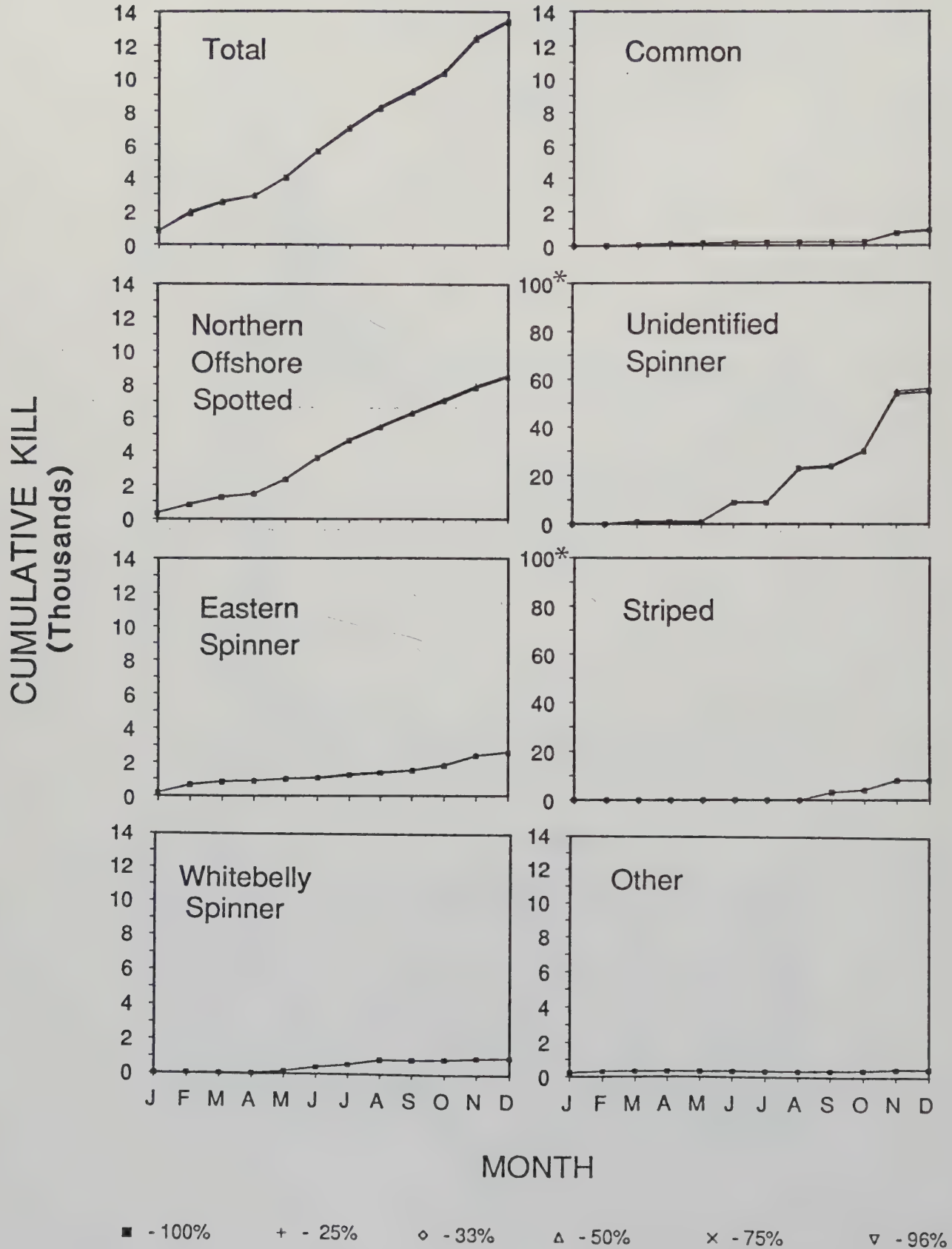


Figure 6. Relative bias in estimated cumulative kill of dolphins by U.S. registered tuna purse-seine vessels fishing in the eastern tropical Pacific Ocean during 1987. Estimates are derived from samples of 25%, 33, 50%, 75% and 96% of observed trips. Individual panels show results for a) total dolphins, b) northern offshore spotted dolphins, c) eastern spinner dolphins, d) whitebelly spinner dolphins, e) common dolphins, f) unidentified spinner dolphins, g) striped dolphins, and h) other dolphins.

## RELATIVE BIAS

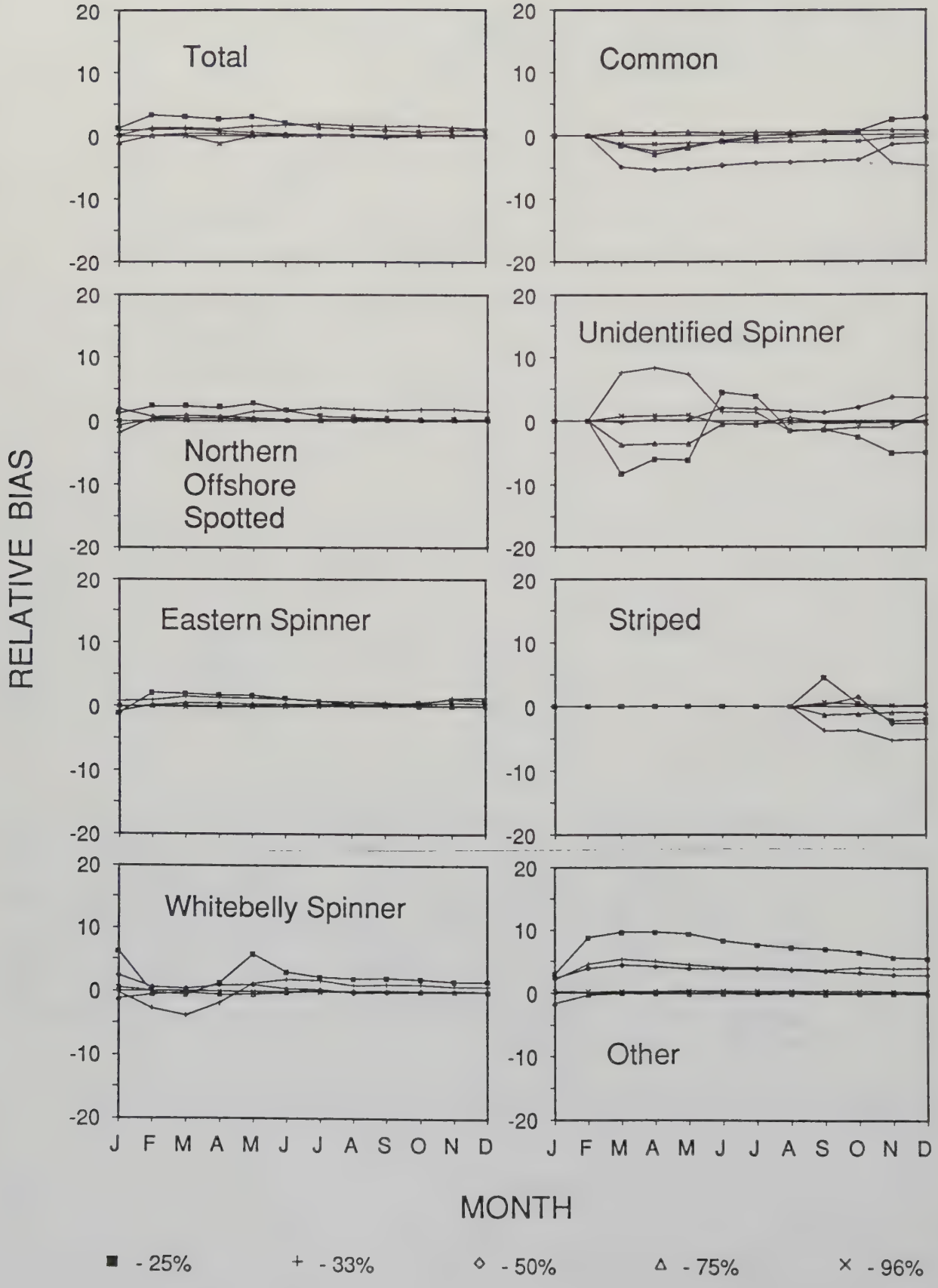


Figure 7. Coefficient of variation for estimated cumulative kill of dolphins by U.S. registered tuna purse-seine vessels fishing in the eastern tropical Pacific Ocean during 1987. Estimates are derived from samples of 25%, 33, 50%, 75% and 96% of observed trips. Individual panels show results for a) total dolphins, b) northern offshore spotted dolphins, c) eastern spinner dolphins, d) whitebelly spinner dolphins, e) common dolphins, f) unidentified spinner dolphins, g) striped dolphins, and h) other dolphins.

# COEFFICIENT OF VARIATION

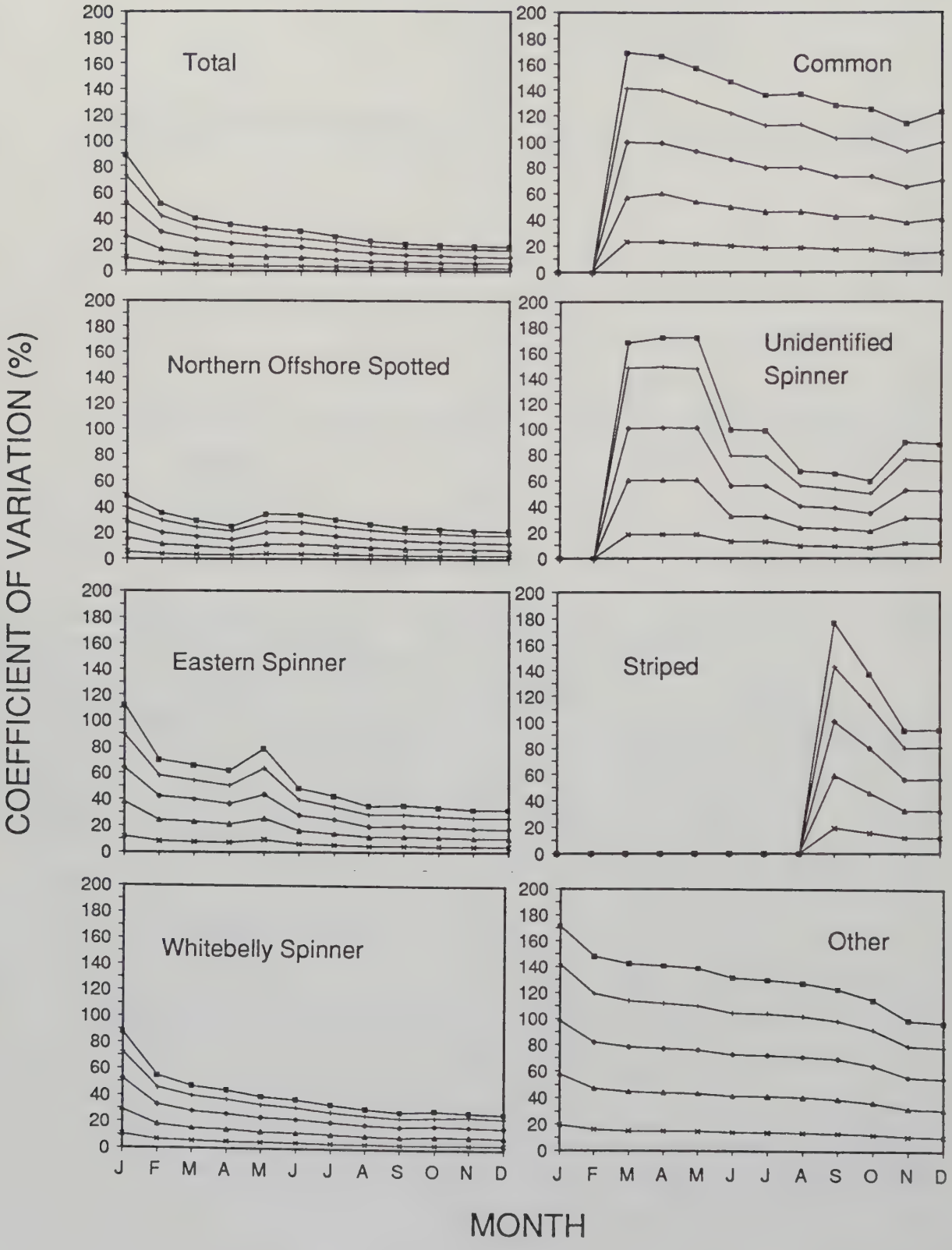


Figure 8. Relative bias in estimates of annual dolphin mortality as a function of fleet size. RBs are presented for 3 dolphin groups (northern offshore spotted, whitebelly spinner, and common dolphins), 4 sizes of fleet (5, 10, 20, and 33 boats) and 3 levels of observer coverage (25, 50, and 75%). Each column shows the average relative bias for a given condition of dolphin, fleet size, and percent coverage. Each set of 3 columns shows results for a particular fleet size. The first 4 sets of columns show results for 25% coverage, the next 4 sets show results for 50% coverage, and the last 4 sets show results for 75% coverage.

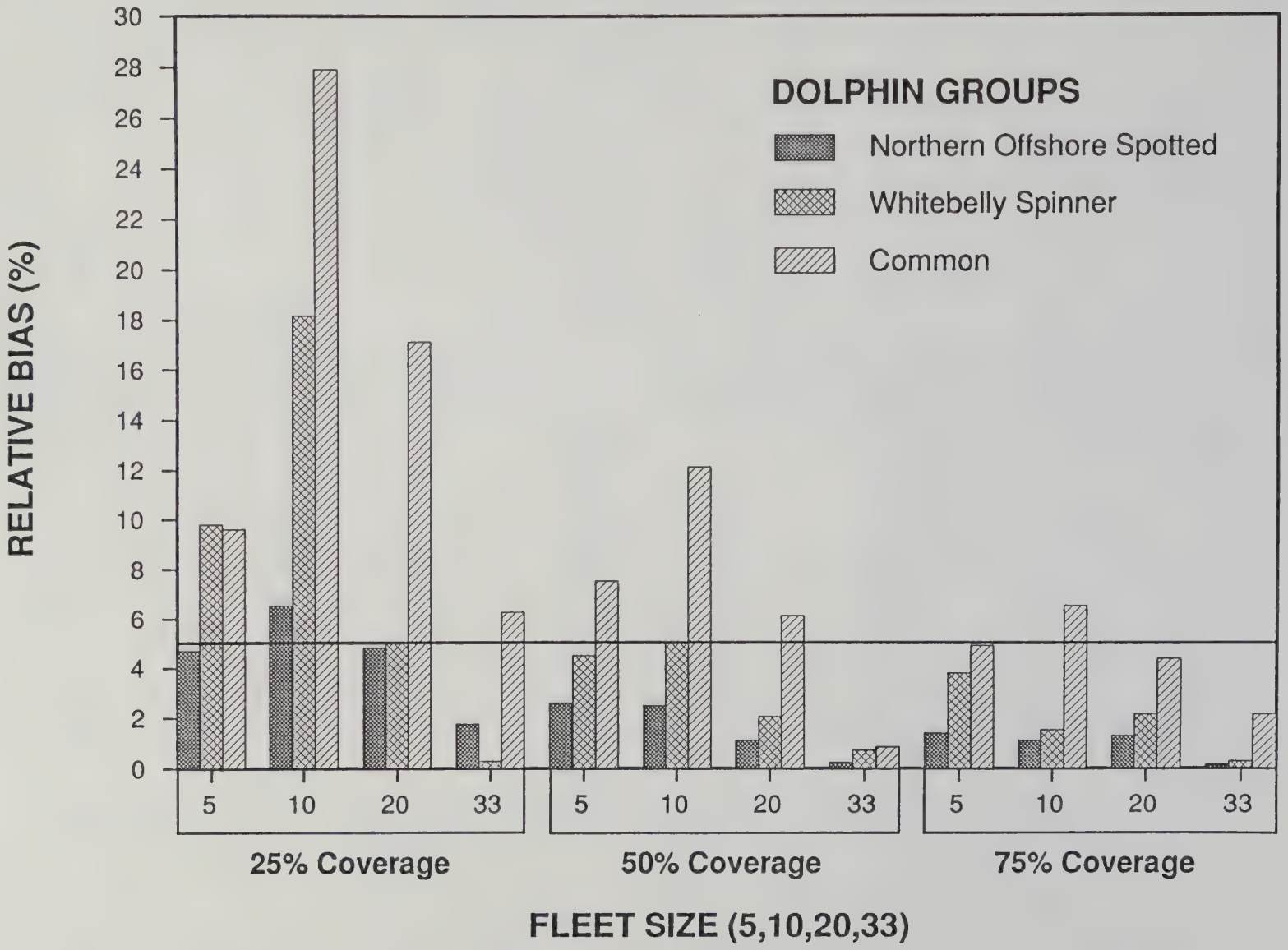

RELATIVE BIAS (%)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
DOLPHIN GROUPS
Northern Offshore Spotted
Whitebelly Spinner
Common
5
10
20
33
5
10
20
33
5
10
20
33
25% Coverage
50% Coverage
75% Coverage
FLEET SIZE (5,10,20,33)

Figure 9. Coefficients of variation for estimates of annual dolphin mortality as a function of fleet size. CVs are presented for 3 dolphin groups (northern offshore spotted, whitebelly spinner, and common dolphins), 4 sizes of fleet (5, 10, 20, and 33 boats) and 3 levels of observer coverage (25, 50, and 75%). Each column shows the average relative bias from 10 replicate simulations for a given condition of dolphin, fleet size, and percent coverage. Each set of 3 columns shows results for a particular fleet size. The first 4 sets of columns show results for 25% coverage, the next 4 sets show results for 50% coverage, and the last 4 sets show results for 75% coverage.

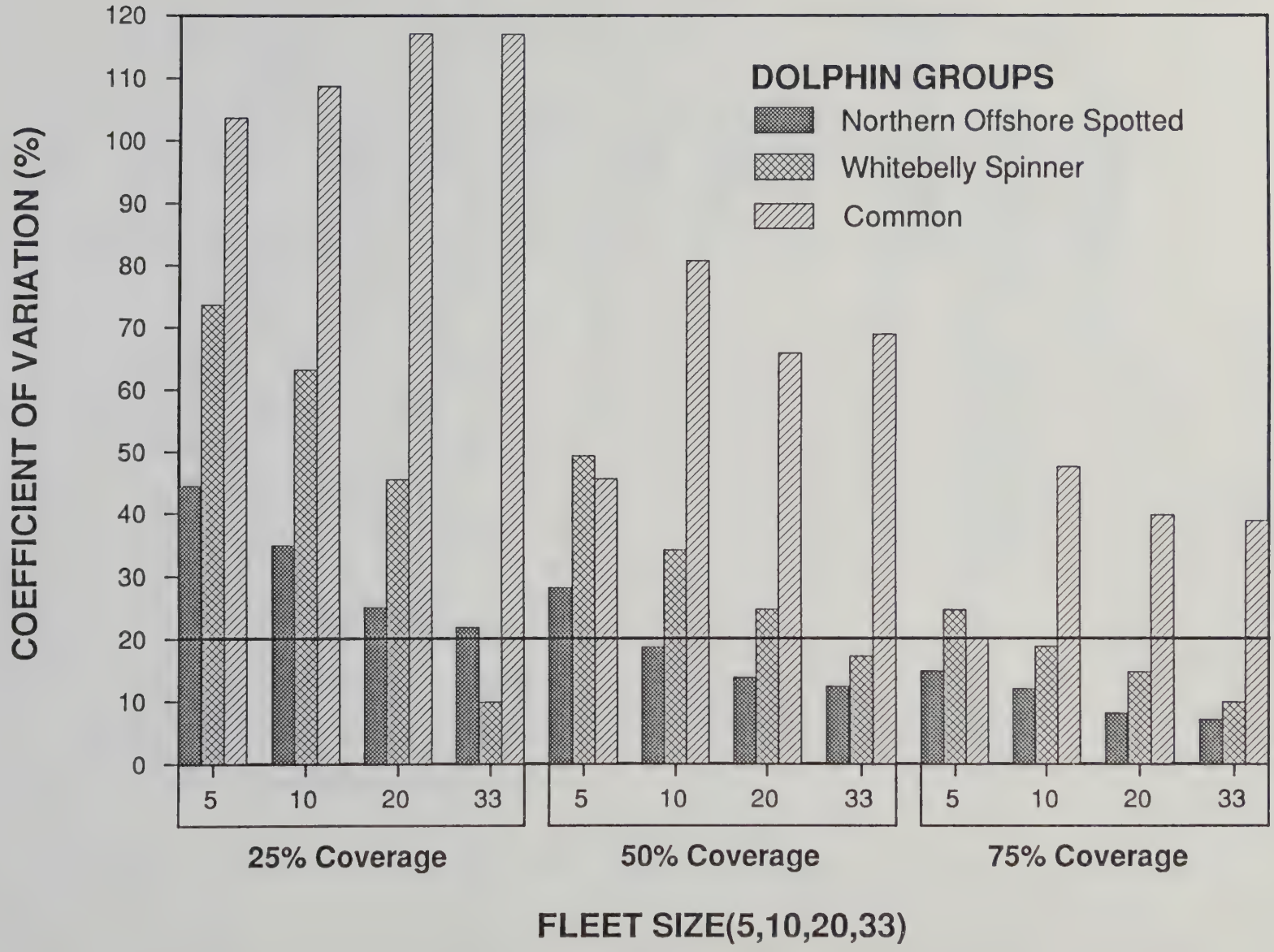

COEFFICIENT OF VARIATION (%)
120
110
100
90
80
70
60
50
40
30
20
10
0
DOLPHIN GROUPS
Northern Offshore Spotted
Whitebelly Spinner
Common
5
10
20
33
25% Coverage
50% Coverage
75% Coverage
FLEET SIZE(5,10,20,33)

Figure 10. Frequency distributions of estimated annual mortality of dolphins incurred by the observed 33-boat U.S. tuna purse-seine fleet during 1987, given 25% or 50% coverage.

## Frequency Distributions

### (33 BOATS)

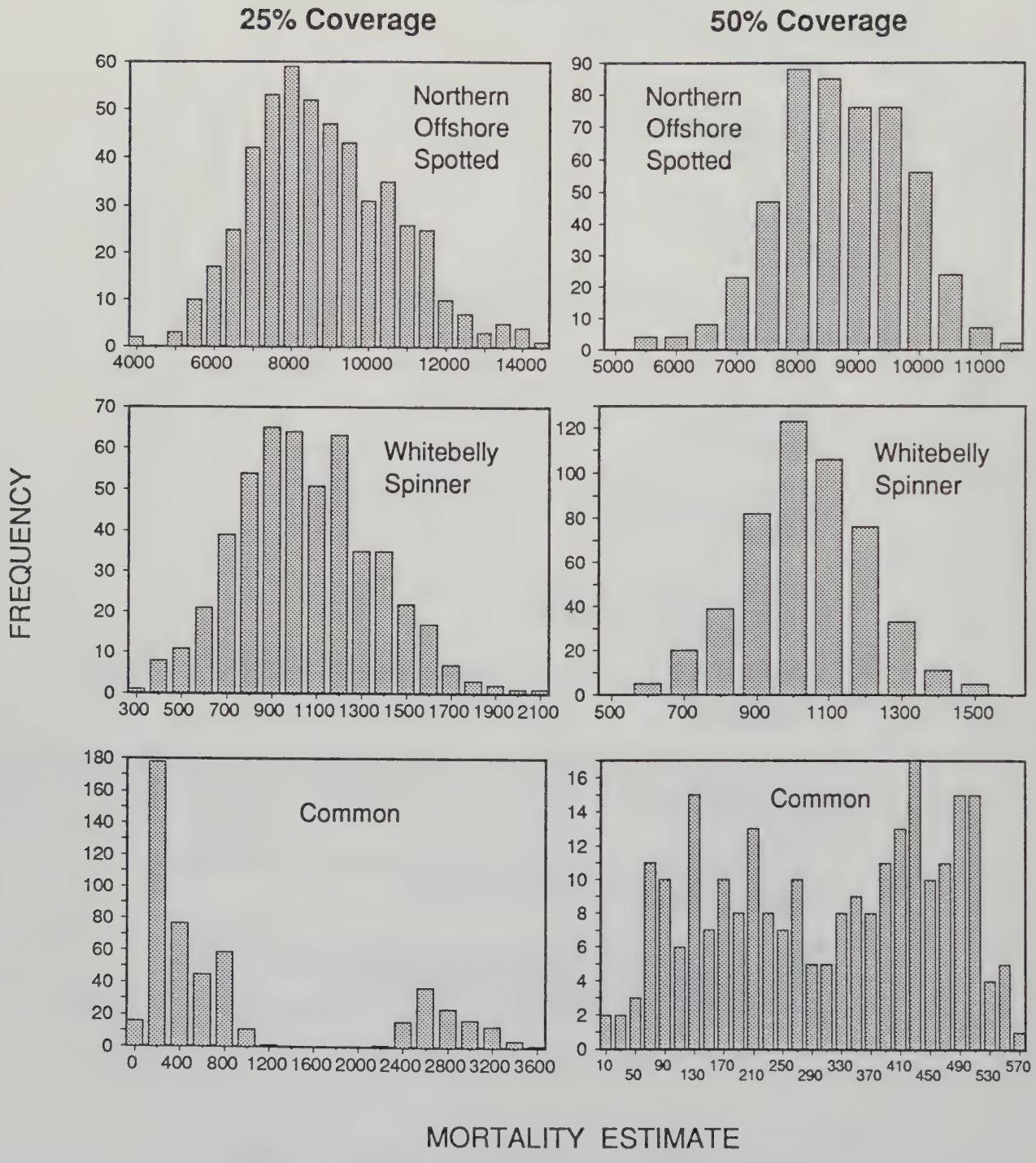


Figure 11. Frequency distributions of estimated annual mortality of northern offshore spotted dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage.

# Frequency Distributions

(MORTALITY ESTIMATE)

## Northern Offshore Spotted

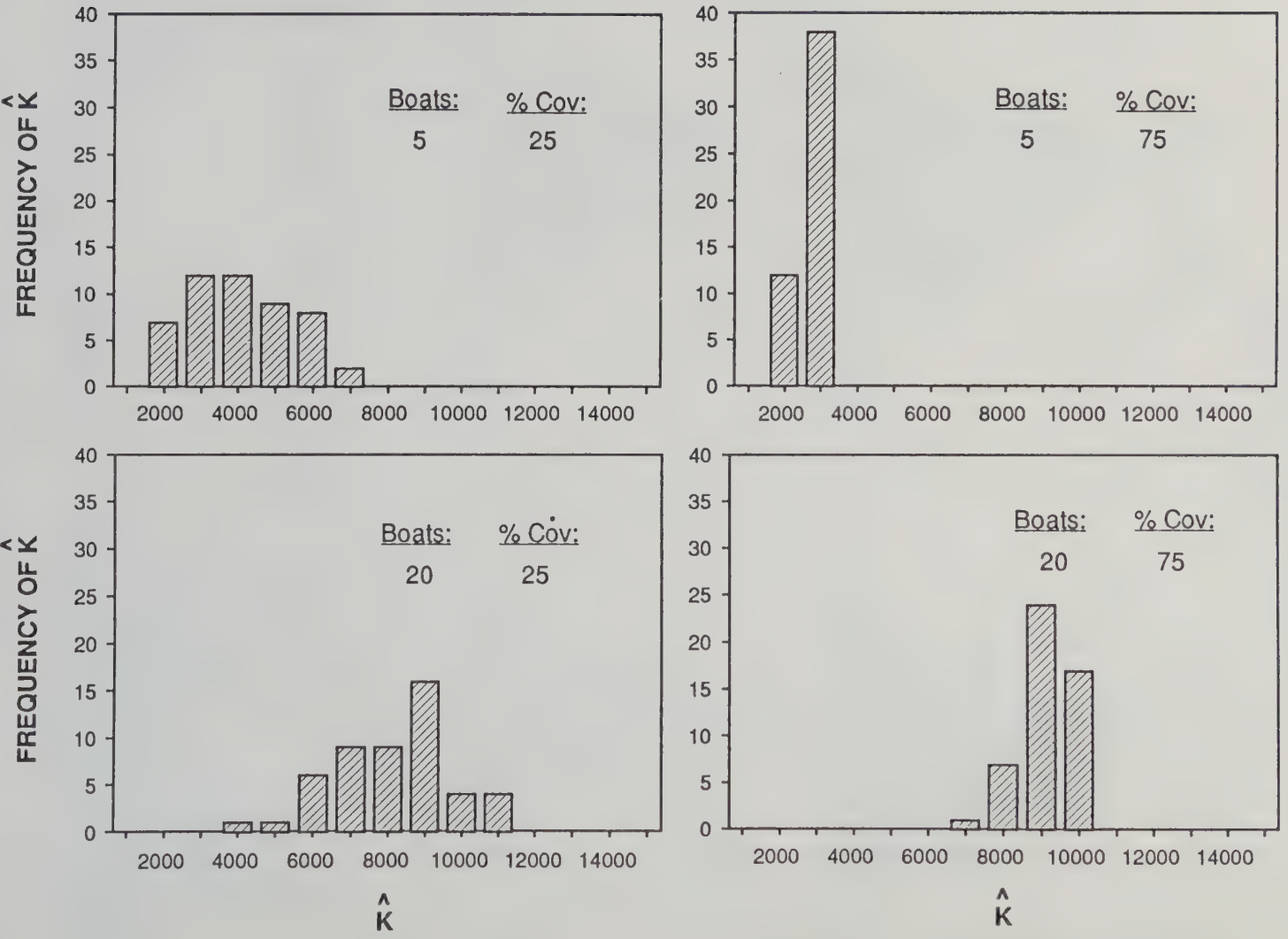


Figure 12. Frequency distributions of estimated annual mortality of whitebelly spinner dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage.

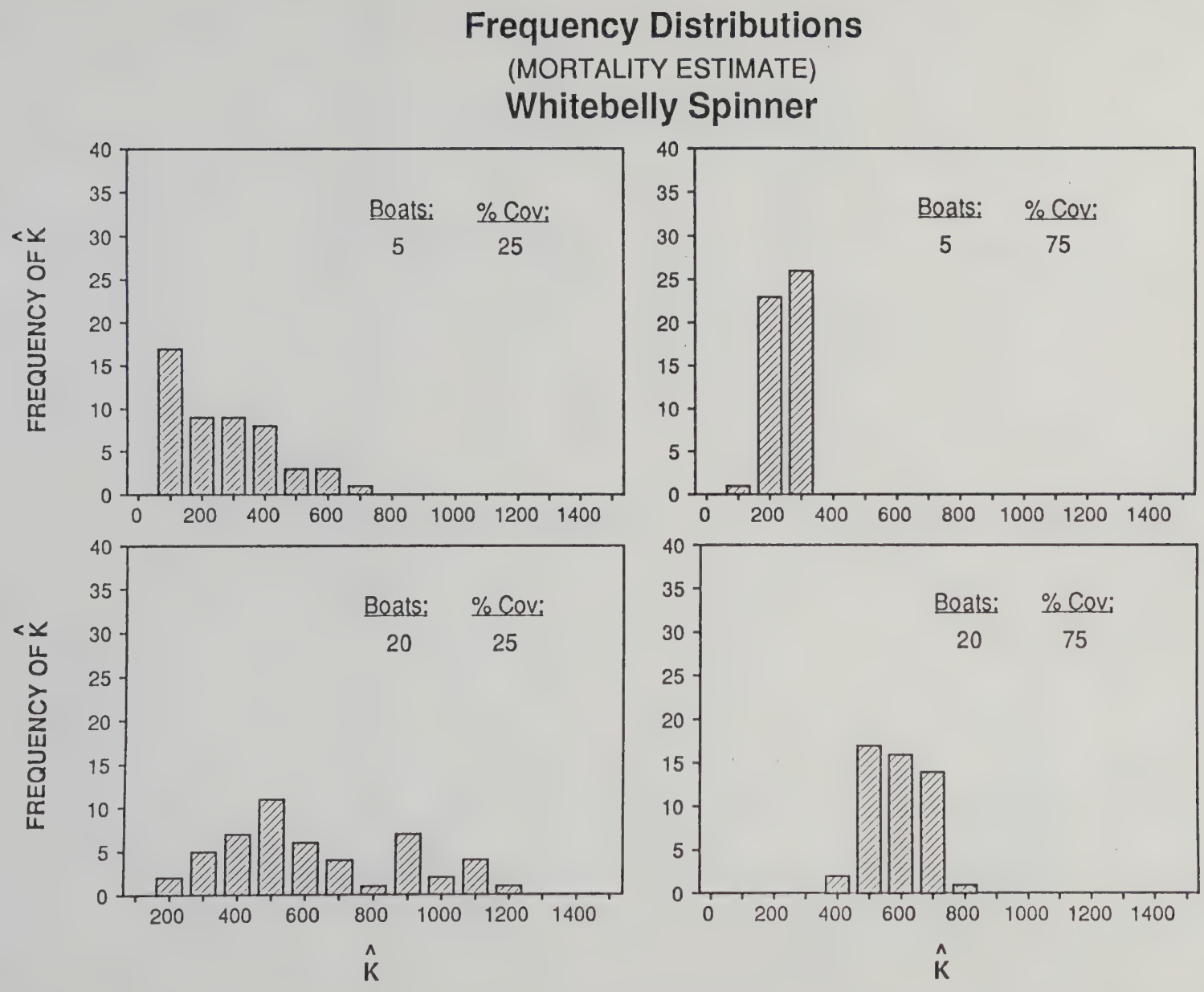

Frequency Distributions
(MORTALITY ESTIMATE)
Whitebelly Spinner
FREQUENCY OF K̂
Boats: 5
% Cov: 25
Boats: 5
% Cov: 75
Boats: 20
% Cov: 25
Boats: 20
% Cov: 75
K̂

Figure 13. Frequency distributions of estimated annual mortality of common dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage.

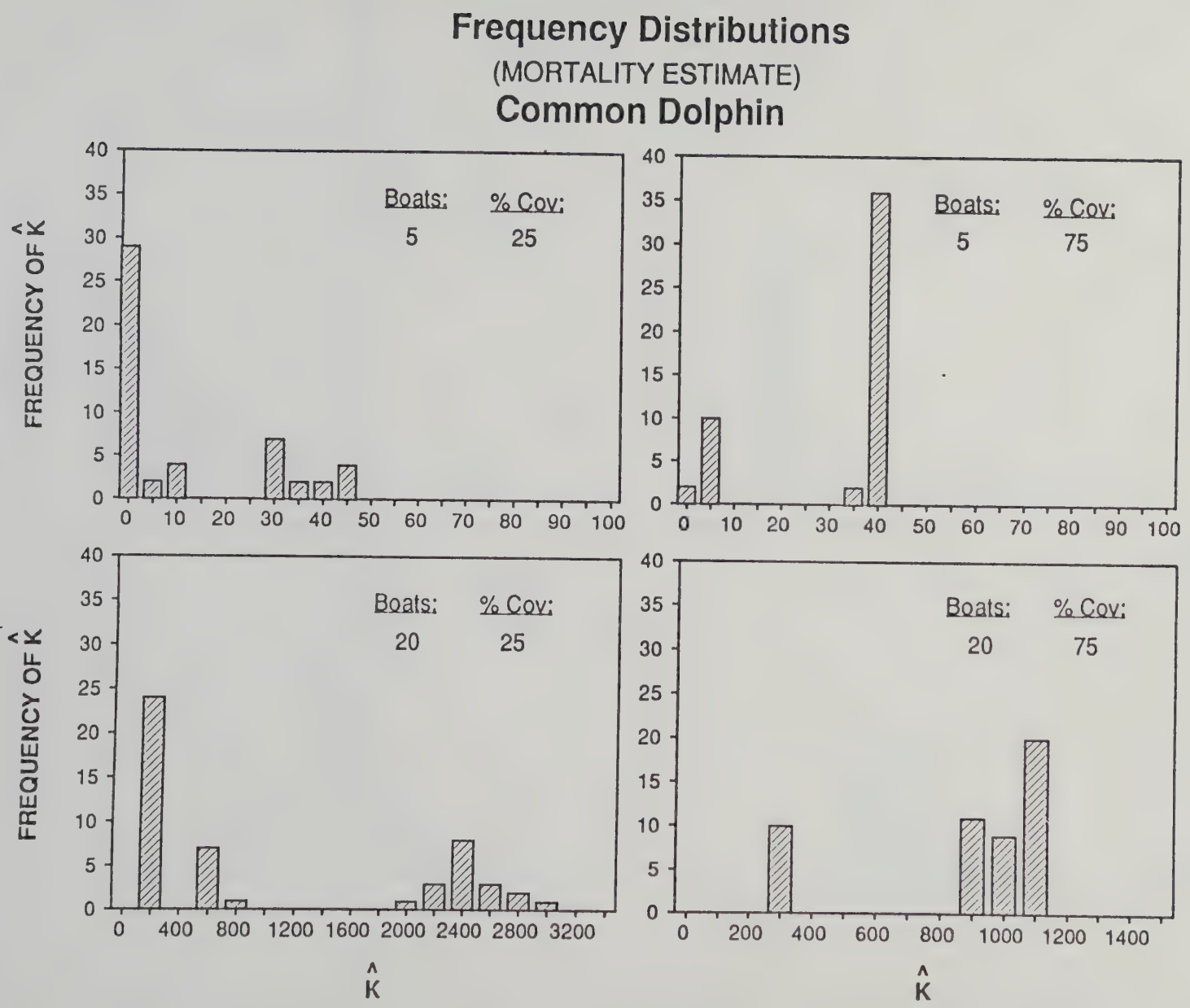

Frequency Distributions
(MORTALITY ESTIMATE)
Common Dolphin
FREQUENCY OF K̂
Boats: 5
% Cov: 25
Boats: 5
% Cov: 75
Boats: 20
% Cov: 25
Boats: 20
% Cov: 75
K̂

Figure 14. Confidence intervals ($\hat{K} \pm 2$ standard errors) for estimated annual mortality of dolphins incurred by the observed 33-boat U.S. tuna purse-seine fleet during 1987, given 25% or 50% coverage.

## CONFIDENCE INTERVALS
## (33 BOATS)

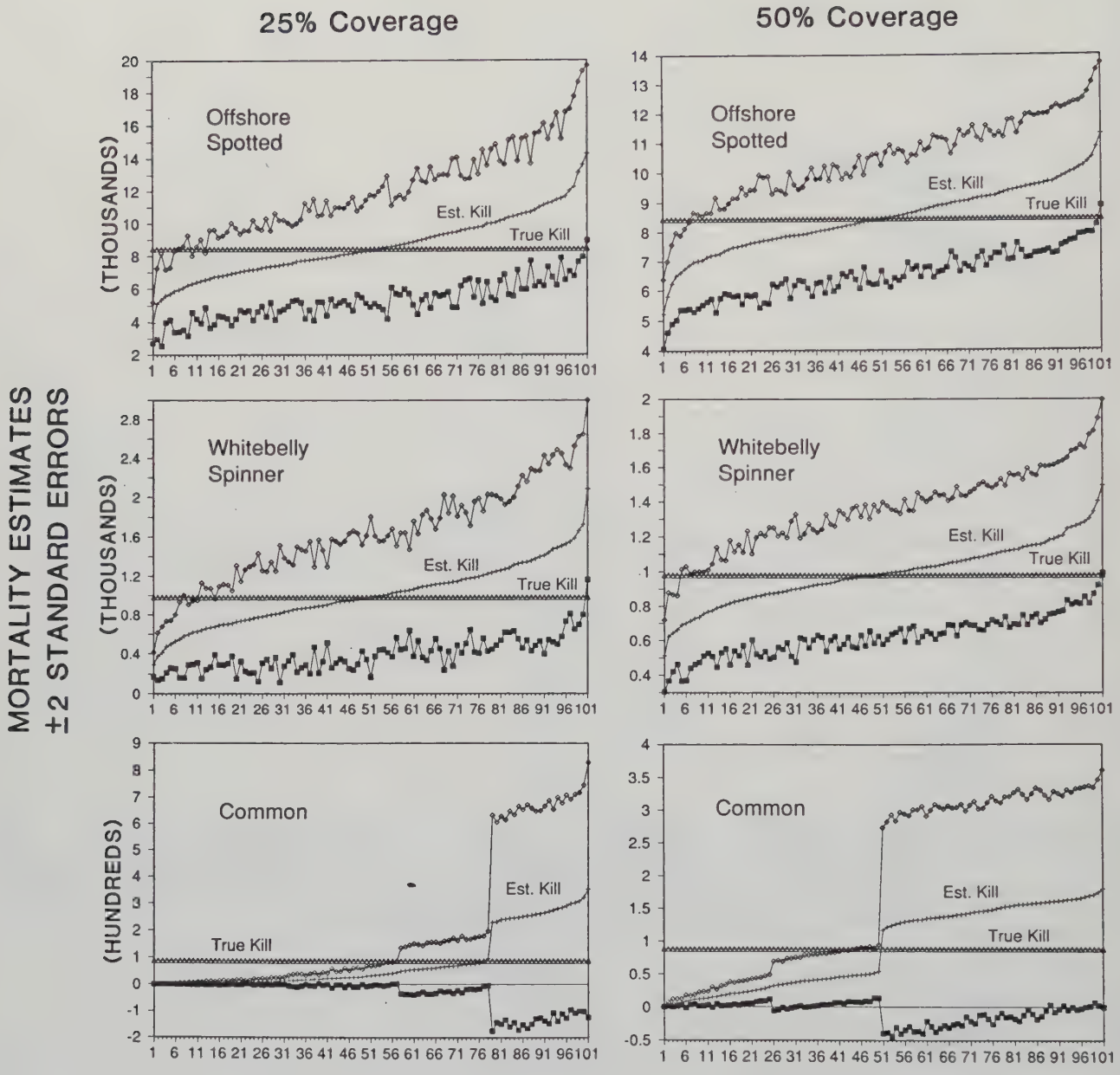


Figure 15. Confidence intervals ($\hat{K} \pm 2$ standard errors) for estimated annual mortality of offshore spotted dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage.

## Mortality Estimates and Confidence Intervals
## Offshore Spotted

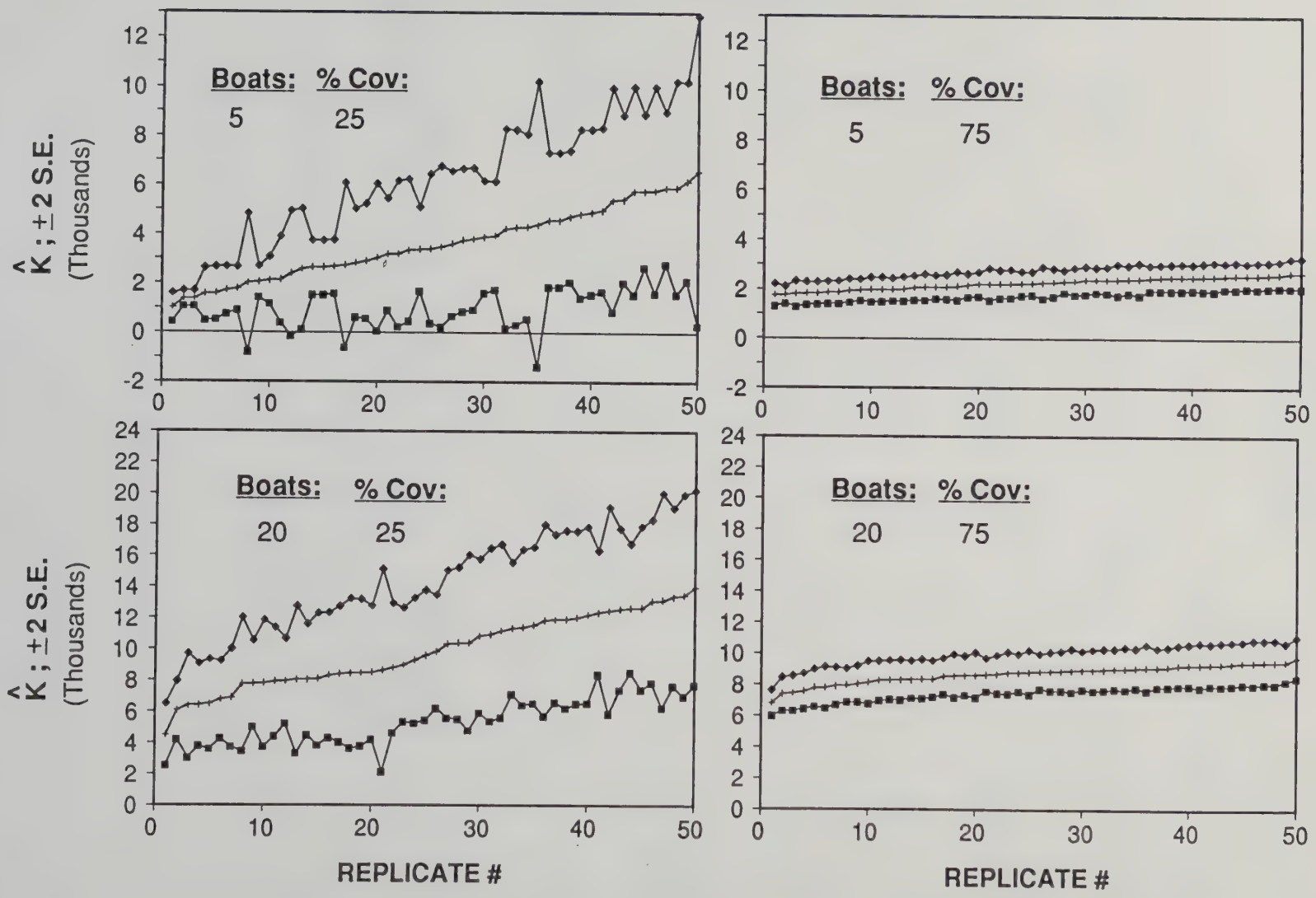


Figure 16. Confidence intervals ($\hat{K} \pm 2$ standard errors) for estimated annual mortality of whitebelly spinner dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage.

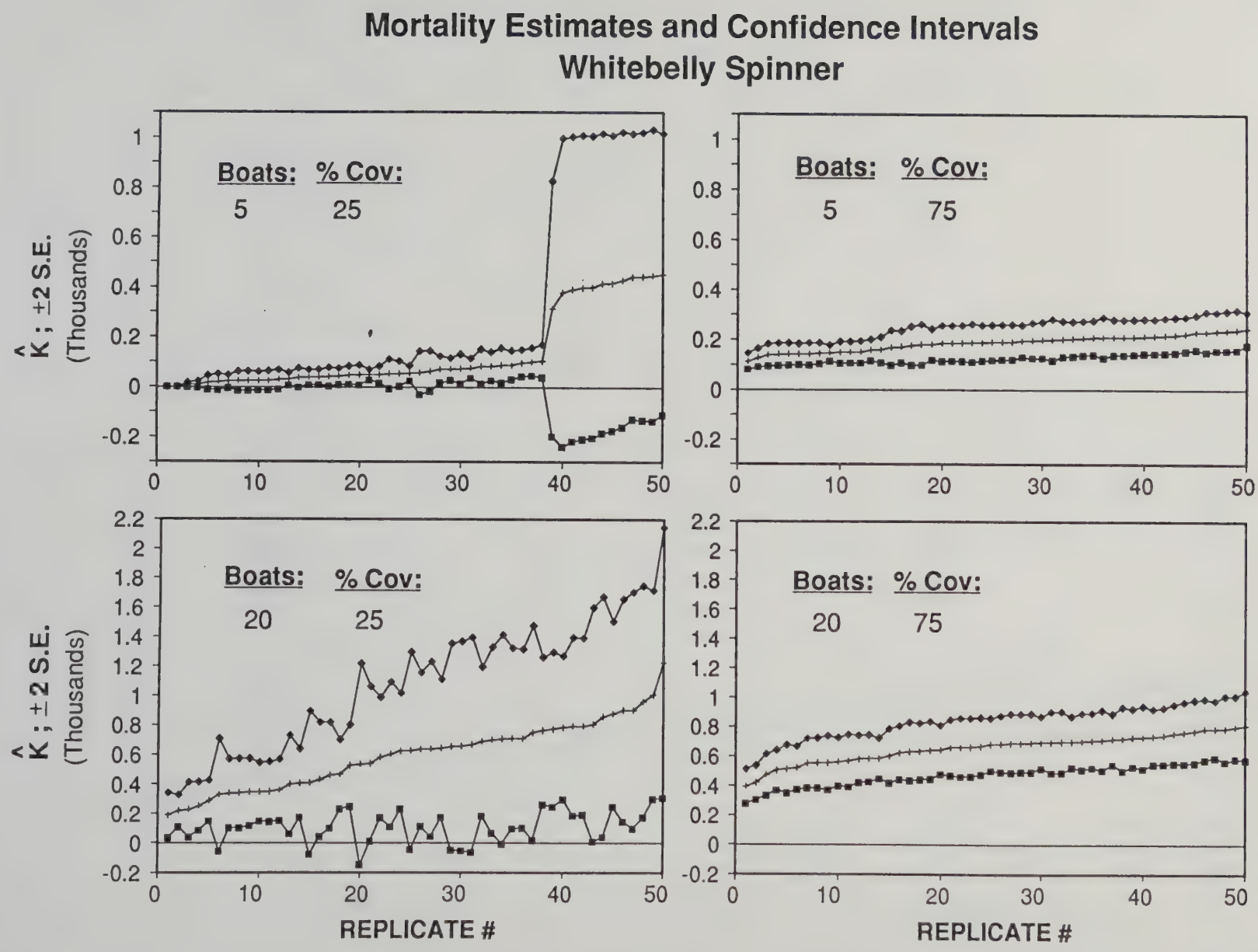
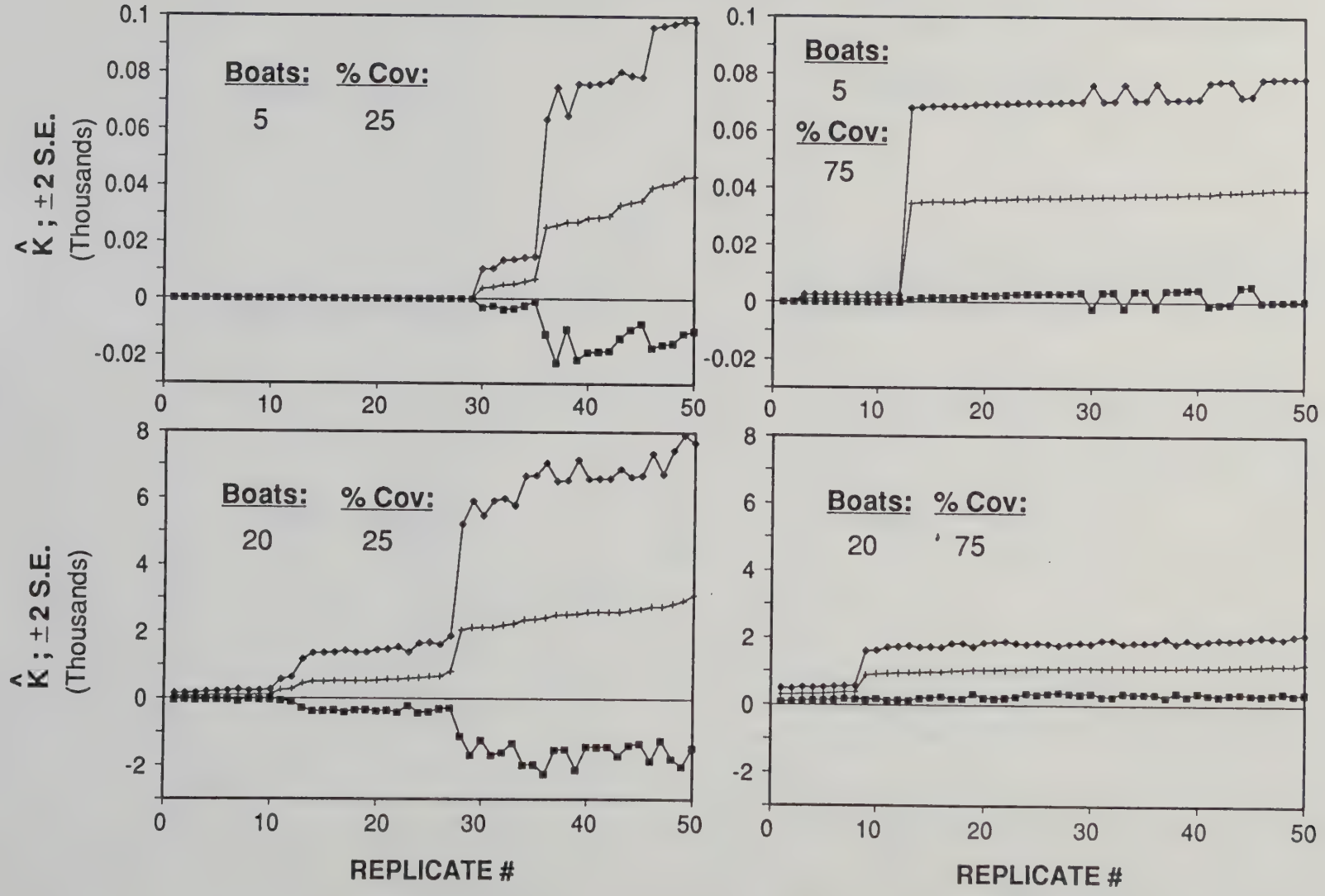

Mortality Estimates and Confidence Intervals
Whitebelly Spinner
Boats: % Cov:
5 25
5 75
20 25
20 75
K̂ ; ±2 S.E. (Thousands)
REPLICATE #

Figure 17. Confidence intervals for estimated annual mortality of common dolphins incurred by a fleet of 5 or 20 boats, sampled at 25% or 75% coverage.

## Mortality Estimates and Confidence Intervals
## Common Dolphins



Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for total dolphins affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 818 | 828 | 1.24 | 88.66 | JAN | 820 | 0.20 | 72.86 | JAN | 826 | 0.95 | 51.89 |
| FEB | 1844 | 1906 | 3.34 | 51.01 | FEB | 1868 | 1.28 | 41.63 | FEB | 1862 | 0.99 | 29.42 |
| MAR | 2517 | 2594 | 3.06 | 39.94 | MAR | 2551 | 1.35 | 32.74 | MAR | 2544 | 1.06 | 23.37 |
| APR | 2898 | 2975 | 2.66 | 34.93 | APR | 2930 | 1.09 | 28.97 | APR | 2920 | 0.76 | 20.73 |
| MAY | 3988 | 4109 | 3.04 | 31.68 | MAY | 4050 | 1.56 | 26.30 | MAY | 4011 | 0.57 | 18.93 |
| JUN | 5586 | 5701 | 2.05 | 29.28 | JUN | 5680 | 1.68 | 24.27 | JUN | 5601 | 0.32 | 17.67 |
| JUL | 6971 | 7062 | 1.30 | 26.02 | JUL | 7100 | 1.86 | 21.34 | JUL | 6984 | 0.19 | 15.51 |
| AUG | 8206 | 8291 | 1.03 | 22.56 | AUG | 8336 | 1.58 | 18.57 | AUG | 8213 | 0.09 | 13.38 |
| SEP | 9163 | 9242 | 0.86 | 20.52 | SEP | 9299 | 1.48 | 17.02 | SEP | 9174 | 0.12 | 12.12 |
| OCT | 10300 | 10370 | 0.85 | 19.63 | OCT | 10456 | 1.52 | 16.39 | OCT | 10315 | 0.15 | 11.53 |
| NOV | 12356 | 12461 | 0.91 | 18.77 | NOV | 12511 | 1.33 | 16.07 | NOV | 12380 | 0.19 | 10.78 |
| DEC | 13390 | 13511 | 0.91 | 18.45 | DEC | 13537 | 1.09 | 15.93 | DEC | 13417 | 0.21 | 10.57 |

| ******* 75% ******* | | | | ******* 96% ******* | | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 818 | 810 | -1.03 | 29.69 | JAN | 182 | 0.07 | 10.17 |
| FEB | 1844 | 1847 | 0.15 | 16.24 | FEB | 1844 | 0.02 | 5.60 |
| MAR | 2517 | 2527 | 0.40 | 12.66 | MAR | 2517 | -0.01 | 4.36 |
| APR | 2898 | 2909 | 0.39 | 11.09 | APR | 2897 | -0.04 | 3.94 |
| MAY | 3988 | 3997 | 0.22 | 10.39 | MAY | 3987 | -0.02 | 3.69 |
| JUN | 5586 | 5593 | 0.13 | 9.78 | JUN | 5585 | -0.02 | 3.40 |
| JUL | 6971 | 6989 | 0.26 | 8.57 | JUL | 6970 | -0.02 | 3.04 |
| AUG | 8206 | 8223 | 0.21 | 7.44 | AUG | 8206 | -0.01 | 2.65 |
| SEP | 9163 | 9183 | 0.22 | 6.74 | SEP | 9163 | 0.00 | 2.39 |
| OCT | 10300 | 10317 | 0.17 | 6.29 | OCT | 10302 | 0.02 | 2.30 |
| NOV | 12356 | 12377 | 0.17 | 6.29 | NOV | 12357 | 0.01 | 2.22 |
| DEC | 13290 | 13407 | 0.13 | 6.16 | DEC | 13392 | 0.02 | 2.18 |

Appendix I, con't.

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for offshore spotters affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 333 | 337 | 1.33 | 48.09 | JAN | 331 | -0.57 | 39.14 | JAN | 335 | 0.60 | 28.01 |
| FEB | 835 | 856 | 2.46 | 35.15 | FEB | 839 | 0.51 | 29.17 | FEB | 839 | 0.73 | 19.92 |
| MAR | 1265 | 1296 | 2.43 | 29.08 | MAR | 1271 | 0.49 | 24.04 | MAR | 1271 | 0.89 | 16.38 |
| APR | 1485 | 1518 | 2.23 | 24.83 | APR | 1492 | 0.48 | 20.97 | APR | 1496 | 0.77 | 14.69 |
| MAY | 2339 | 2406 | 2.86 | 34.13 | MAY | 2375 | 1.53 | 28.52 | MAY | 2352 | 0.56 | 19.97 |
| JUN | 3596 | 3658 | 1.72 | 33.73 | JUN | 3676 | 1.71 | 27.95 | JUN | 3604 | 0.22 | 19.77 |
| JUL | 4634 | 4676 | 0.90 | 30.07 | JUL | 4731 | 2.10 | 24.72 | JUL | 4636 | 0.04 | 17.46 |
| AUG | 5417 | 5455 | 0.70 | 26.56 | AUG | 5517 | 1.85 | 21.80 | AUG | 5418 | 0.01 | 15.39 |
| SEP | 6221 | 6251 | 0.48 | 23.77 | SEP | 6326 | 1.68 | 19.73 | SEP | 6225 | 0.07 | 13.78 |
| OCT | 7002 | 7019 | 0.24 | 22.88 | OCT | 7129 | 1.81 | 19.14 | OCT | 7008 | 0.09 | 13.05 |
| NOV | 7794 | 7821 | 0.35 | 21.73 | NOV | 7937 | 1.83 | 18.20 | NOV | 7803 | 0.11 | 12.14 |
| DEC | 8437 | 8475 | 0.46 | 21.35 | DEC | 8568 | 1.56 | 18.10 | DEC | 8452 | 0.18 | 11.91 |

| ******* 75% ******* | | | | ******* 96% ******* | | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 333 | 331 | -0.72 | 16.11 | JAN | 333 | 0.00 | 5.50 |
| FEB | 835 | 838 | 0.33 | 11.38 | FEB | 836 | 0.10 | 3.74 |
| MAR | 1265 | 1271 | 0.48 | 9.53 | MAR | 1266 | 0.09 | 3.18 |
| APR | 1485 | 1492 | 0.47 | 8.21 | APR | 1486 | 0.07 | 2.83 |
| MAY | 2339 | 2344 | 0.23 | 11.38 | MAY | 2341 | 0.08 | 3.90 |
| JUN | 3596 | 3600 | 0.11 | 11.29 | JUN | 3591 | 0.04 | 3.89 |
| JUL | 4634 | 4649 | 0.33 | 9.86 | JUL | 4635 | 0.02 | 3.49 |
| AUG | 5417 | 5432 | 0.27 | 8.69 | AUG | 5419 | 0.04 | 3.09 |
| SEP | 6221 | 6239 | 0.28 | 7.77 | SEP | 6223 | 0.04 | 2.74 |
| OCT | 7002 | 7020 | 0.25 | 7.54 | OCT | 7005 | 0.04 | 2.64 |
| NOV | 7794 | 7811 | 0.22 | 7.16 | NOV | 7797 | 0.04 | 2.51 |
| DEC | 8437 | 8450 | 0.16 | 6.98 | DEC | 8441 | 0.05 | 2.45 |

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for eastern spinners affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| | ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 222 | 220 | -1.12 | 87.50 | JAN | 224 | 0.79 | 72.55 | JAN | 222 | -0.13 | 52.60 |
| FEB | 669 | 683 | 2.09 | 54.74 | FEB | 675 | 0.90 | 45.83 | FEB | 669 | 0.00 | 32.87 |
| MAR | 839 | 855 | 1.91 | 47.19 | MAR | 852 | 1.50 | 39.73 | MAR | 843 | 0.43 | 28.19 |
| APR | 902 | 918 | 1.73 | 44.19 | APR | 914 | 1.32 | 37.36 | APR | 906 | 0.42 | 26.34 |
| MAY | 1016 | 1033 | 1.71 | 39.48 | MAY | 1029 | 1.25 | 33.36 | MAY | 1019 | 0.30 | 23.59 |
| JUN | 1087 | 1100 | 1.22 | 37.21 | JUN | 1100 | 1.15 | 31.23 | JUN | 1090 | 0.28 | 22.39 |
| JUL | 1249 | 1259 | 0.78 | 33.41 | JUL | 1259 | 0.82 | 27.87 | JUL | 1253 | 0.34 | 20.26 |
| AUG | 1389 | 1394 | 0.34 | 30.49 | AUG | 1398 | 0.66 | 25.39 | AUG | 1392 | 0.22 | 18.44 |
| SEP | 1506 | 1511 | 0.34 | 28.13 | SEP | 1515 | 0.58 | 23.48 | SEP | 1509 | 0.22 | 16.96 |
| OCT | 1791 | 1801 | 0.57 | 29.35 | OCT | 1795 | 0.24 | 24.22 | OCT | 1795 | 0.21 | 17.82 |
| NOV | 2364 | 2578 | 0.96 | 27.88 | NOV | 2393 | 1.24 | 24.68 | NOV | 2567 | 0.45 | 17.08 |
| DEC | 2557 | 2578 | 0.83 | 26.92 | DEC | 2591 | 1.32 | 23.61 | DEC | 2567 | 0.38 | 16.35 |

| | ******* 75% ******* | | | | ******* 96% ******* | | | |
|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 222 | 220 | -0.86 | 29.05 | JAN | 222 | 0.01 | 10.28 |
| FEB | 669 | 670 | 0.16 | 18.03 | FEB | 668 | -0.15 | 6.49 |
| MAR | 839 | 843 | 0.48 | 15.21 | MAR | 838 | -0.17 | 5.54 |
| APR | 902 | 906 | 0.48 | 14.18 | APR | 901 | -0.15 | 5.20 |
| MAY | 1016 | 1020 | 0.36 | 12.68 | MAY | 1014 | -0.15 | 4.67 |
| JUN | 1087 | 1091 | 0.35 | 12.06 | JUN | 1086 | -0.12 | 4.44 |
| JUL | 1249 | 1251 | 0.16 | 10.94 | JUL | 1248 | -0.07 | 3.98 |
| AUG | 1389 | 1391 | 0.12 | 10.05 | AUG | 1388 | -0.05 | 3.65 |
| SEP | 1506 | 1508 | 0.10 | 9.18 | SEP | 1505 | -0.06 | 3.37 |
| OCT | 1791 | 1790 | 0.25 | 7.54 | OCT | 1791 | 0.01 | 3.38 |
| NOV | 2364 | 2363 | -0.04 | 9.57 | NOV | 2365 | 0.03 | 3.34 |
| DEC | 2557 | 2556 | -0.05 | 9.06 | DEC | 2558 | 0.03 | 3.26 |

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for whitebelly spinners affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 13 | 13 | 6.24 | 112.27 | JAN | 13 | -2.23 | 89.89 | JAN | 13 | 2.48 | 63.76 |
| FEB | 32 | 32 | -0.25 | 69.65 | FEB | 31 | -2.68 | 57.97 | FEB | 32 | 0.53 | 42.29 |
| MAR | 36 | 36 | -0.57 | 65.69 | MAR | 35 | -3.80 | 54.28 | MAR | 36 | 0.34 | 39.83 |
| APR | 43 | 44 | 1.27 | 61.66 | APR | 42 | -1.83 | 50.47 | APR | 43 | 0.95 | 36.44 |
| MAY | 152 | 161 | 5.81 | 78.47 | MAY | 154 | 1.22 | 63.54 | MAY | 155 | 0.99 | 43.59 |
| JUN | 387 | 398 | 2.96 | 48.34 | JUN | 394 | 1.85 | 39.54 | JUN | 388 | 0.34 | 27.80 |
| JUL | 557 | 569 | 2.21 | 42.27 | JUL | 566 | 1.63 | 34.08 | JUL | 558 | 0.25 | 24.55 |
| AUG | 848 | 865 | 1.95 | 34.87 | AUG | 856 | 0.92 | 28.27 | AUG | 846 | -0.26 | 19.41 |
| SEP | 851 | 868 | 2.05 | 35.18 | SEP | 860 | 1.02 | 28.37 | SEP | 849 | -0.18 | 19.62 |
| OCT | 887 | 904 | 1.91 | 33.81 | OCT | 897 | 1.02 | 27.40 | OCT | 886 | -0.06 | 18.89 |
| NOV | 962 | 977 | 1.53 | 31.97 | NOV | 969 | 0.71 | 25.87 | NOV | 962 | -0.02 | 17.67 |
| DEC | 981 | 996 | 1.55 | 31.79 | DEC | 988 | 0.73 | 25.73 | DEC | 981 | -0.04 | 17.46 |

| ******* 75% ******* | | | | ******* 96% ******* | | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 13 | 13 | -1.16 | 37.86 | JAN | 13 | 0.51 | 11.89 |
| FEB | 32 | 32 | -0.59 | 24.19 | FEB | 32 | 0.06 | 8.10 |
| MAR | 36 | 36 | -0.28 | 22.70 | MAR | 36 | 0.04 | 7.54 |
| APR | 43 | 43 | -0.58 | 21.06 | APR | 43 | -0.02 | 7.06 |
| MAY | 152 | 151 | -0.49 | 25.13 | MAY | 152 | -0.11 | 9.24 |
| JUN | 387 | 386 | -0.22 | 15.92 | JUN | 387 | -0.10 | 5.90 |
| JUL | 557 | 557 | 0.03 | 13.82 | JUL | 556 | -0.14 | 5.16 |
| AUG | 848 | 849 | 0.07 | 11.29 | AUG | 847 | -0.11 | 4.26 |
| SEP | 851 | 852 | 0.08 | 11.37 | SEP | 850 | -0.09 | 4.30 |
| OCT | 887 | 888 | 0.06 | 10.97 | OCT | 886 | -0.08 | 4.15 |
| NOV | 962 | 962 | 0.04 | 10.33 | NOV | 961 | -0.14 | 3.92 |
| DEC | 981 | 981 | 0.01 | 10.25 | DEC | 980 | -0.13 | 3.89 |

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for striped dolphins affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| | ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| MAR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| APR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| MAY | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| JUN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| JUL | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| AUG | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| SEP | 3 | 3 | 4.57 | 176.83 | 3 | -3.74 | 142.86 | 3 | 0.35 | 100.35 | |
| OCT | 4 | 4 | 0.50 | 136.79 | 4 | -3.68 | 112.45 | 4 | 1.51 | 79.76 | |
| NOV | 8 | 8 | -2.22 | 93.33 | 8 | -5.26 | 79.86 | 8 | -2.66 | 55.52 | |
| DEC | 8 | 8 | -1.97 | 93.59 | 8 | -5.09 | 80.12 | 8 | -2.61 | 55.61 | |

| | ******* 75% ******* | | | | ******* 96% ******* | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| MAR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| APR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| MAY | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| JUN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| JUL | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| AUG | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| SEP | 3 | 3 | -1.32 | 58.76 | 3 | 0.62 | 18.99 |
| OCT | 4 | 4 | -1.19 | 45.50 | 4 | 0.38 | 15.24 |
| NOV | 8 | 8 | -0.97 | 31.91 | 8 | 0.16 | 11.34 |
| DEC | 8 | 8 | -0.96 | 31.97 | 8 | 0.17 | 11.34 |

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for unidentified dolphins affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| | ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | JAN | 0 | 0.00 | 0.00 |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | FEB | 0 | 0.00 | 0.00 |
| MAR | 1 | 0.92 | -8.27 | 168.13 | 1 | 7.51 | 148.14 | MAR | 1 | -0.25 | 100.58 |
| APR | 1 | 0.94 | -6.02 | 172.16 | 1 | 8.30 | 149.00 | APR | 1 | 0.18 | 100.92 |
| MAY | 1 | 0.94 | -6.19 | 171.76 | 1 | 7.21 | 147.33 | MAY | 1 | 0.13 | 100.81 |
| JUN | 9 | 9 | 4.45 | 99.55 | 9 | 1.39 | 78.76 | JUN | 9 | 2.00 | 55.72 |
| JUL | 9 | 9 | 3.83 | 98.76 | 9 | 1.27 | 78.48 | JUL | 9 | 1.92 | 55.62 |
| AUG | 23 | 23 | -1.53 | 67.10 | 23 | -1.59 | 55.61 | AUG | 23 | 1.48 | 39.87 |
| SEP | 24 | 24 | -1.40 | 65.06 | 24 | -1.41 | 53.37 | SEP | 24 | 1.28 | 38.53 |
| OCT | 30 | 29 | -2.56 | 59.30 | 30 | -1.08 | 49.66 | OCT | 31 | 2.09 | 34.40 |
| NOV | 54 | 52 | -5.08 | 89.27 | 53 | -1.10 | 75.81 | NOV | 56 | 3.64 | 52.00 |
| DEC | 55 | 52 | -4.96 | 87.69 | 54 | -0.94 | 74.64 | DEC | 57 | 3.50 | 51.13 |

| | ******* 75% ******* | | | | ******* 96% ******* | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| MAR | 1 | 0.96 | -3.77 | 60.16 | 1 | 0.79 | 18.21 |
| APR | 1 | 0.96 | -3.58 | 60.24 | 1 | 0.84 | 18.20 |
| MAY | 1 | 0.96 | -3.59 | 60.21 | 1 | 0.87 | 18.19 |
| JUN | 9 | 9 | -0.56 | 32.15 | 9 | -0.47 | 12.57 |
| JUL | 9 | 9 | -0.60 | 32.03 | 9 | -0.49 | 12.48 |
| AUG | 23 | 23 | -0.51 | 23.26 | 23 | -0.34 | 9.15 |
| SEP | 24 | 24 | -0.44 | 22.52 | 24 | -0.30 | 8.76 |
| OCT | 30 | 30 | -0.41 | 20.53 | 30 | -0.29 | 7.69 |
| NOV | 54 | 54 | -0.37 | 30.71 | 54 | -0.29 | 11.07 |
| DEC | 55 | 55 | -0.39 | 30.21 | 55 | -0.27 | 10.86 |

Appendix I, con't.

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for common dolphins affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| | ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | |
| MAR | 50 | 49 | -1.49 | 168.88 | 49 | -2.33 | 141.26 | 48 | -4.87 | 99.73 | |
| APR | 137 | 133 | -2.93 | 166.31 | 134 | -1.69 | 139.72 | 130 | -5.37 | 99.12 | |
| MAY | 147 | 144 | -1.88 | 157.04 | 145 | -0.85 | 130.60 | 139 | -5.21 | 92.46 | |
| JUN | 159 | 158 | -0.71 | 146.54 | 158 | -0.52 | 121.65 | 152 | -4.64 | 85.95 | |
| JUL | 173 | 173 | -0.04 | 136.02 | 172 | -0.52 | 112.60 | 166 | -4.29 | 79.42 | |
| AUG | 173 | 174 | 0.29 | 136.69 | 173 | -0.29 | 112.90 | 166 | -4.21 | 72.51 | |
| SEP | 191 | 192 | 0.58 | 124.74 | 192 | 0.32 | 102.30 | 183 | -4.02 | 72.28 | |
| OCT | 191 | 192 | 0.68 | 124.85 | 192 | 0.39 | 102.19 | 184 | -3.91 | 72.38 | |
| NOV | 714 | 731 | 2.42 | 113.52 | 682 | -4.42 | 91.74 | 704 | -1.46 | 64.20 | |
| DEC | 882 | 906 | 2.73 | 122.49 | 839 | -4.91 | 98.67 | 870 | -1.33 | 69.35 | |

| | ******* 75% ******* | | | | ******* 96% ******* | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | -99.99 |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | -99.99 |
| MAR | 50 | 50 | 0.59 | 57.01 | 49 | -1.24 | 22.82 |
| APR | 137 | 138 | 0.51 | 56.93 | 135 | -1.23 | 22.80 |
| MAY | 147 | 148 | 0.60 | 53.37 | 145 | -1.10 | 21.21 |
| JUN | 159 | 160 | 0.45 | 49.37 | 157 | -1.03 | 19.61 |
| JUL | 173 | 174 | 0.51 | 45.72 | 171 | -0.99 | 18.06 |
| AUG | 173 | 174 | 0.52 | 45.75 | 171 | -0.97 | 18.08 |
| SEP | 191 | 192 | 0.62 | 41.74 | 189 | -0.95 | 16.48 |
| OCT | 191 | 192 | 0.62 | 41.74 | 198 | -0.94 | 16.48 |
| NOV | 714 | 719 | 0.73 | 36.79 | 711 | -0.35 | 13.32 |
| DEC | 882 | 888 | 0.67 | 39.73 | 880 | -0.28 | 14.29 |

Appendix I, con't.

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for striped dolphins affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based 1000 replicate simulations. Percents refer to percent of sampling coverage of trips selected from the set of all observed trips.

| | ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | MONTH | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | JAN | 0 | 0.00 | 0.00 |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | FEB | 0 | 0.00 | 0.00 |
| MAR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | MAR | 0 | 0.00 | 0.00 |
| APR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | APR | 0 | 0.00 | 0.00 |
| MAY | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | MAY | 0 | 0.00 | 0.00 |
| JUN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | JUN | 0 | 0.00 | 0.00 |
| JUL | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | JUL | 0 | 0.00 | 0.00 |
| AUG | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 | AUG | 0 | 0.00 | 0.00 |
| SEP | 3 | 3 | 4.57 | 176.83 | 3 | -3.74 | 142.86 | SEP | 3 | 0.35 | 100.35 |
| OCT | 4 | 4 | 0.50 | 136.79 | 4 | -3.68 | 112.45 | OCT | 4 | 1.51 | 79.76 |
| NOV | 8 | 8 | -2.22 | 93.33 | 8 | -5.26 | 79.86 | NOV | 8 | -2.66 | 55.52 |
| DEC | 8 | 8 | -1.97 | 93.59 | 8 | -5.09 | 80.12 | DEC | 8 | -2.61 | 55.61 |

| | ******* 75% ******* | | | | ******* 96% ******* | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| FEB | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| MAR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| APR | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| MAY | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| JUN | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| JUL | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| AUG | 0 | 0 | 0.00 | 0.00 | 0 | 0.00 | 0.00 |
| SEP | 3 | 3 | -1.32 | 58.76 | 3 | 0.62 | 18.99 |
| OCT | 4 | 4 | -1.19 | 45.50 | 4 | 0.38 | 15.24 |
| NOV | 8 | 8 | -0.97 | 31.91 | 8 | 0.16 | 11.34 |
| DEC | 8 | 8 | -0.96 | 31.97 | 8 | 0.17 | 11.34 |

Appendix 1, con't.

Cumulative observed and estimated mortality, relative bias and coefficient of variation of the estimate for other dolphins affected by the U.S. tuna purse-seine fleet fishing in the eastern tropical Pacific Ocean during 1987. Results are based on 1000 replicate simulations. Percents refer to percent oc sampling coverage of trips selected from the set of all observed trips.

| | ******* 25% ******* | | | | ******* 33% ******* | | | | ******* 50% ******* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV | |
| JAN | 250 | 257 | 2.69 | 171.48 | 252 | 0.82 | 141.95 | 256 | 2.31 | 98.48 | |
| FEB | 308 | 335 | 8.80 | 148.02 | 322 | 4.61 | 119.18 | 320 | 3.89 | 82.01 | |
| MAR | 326 | 357 | 9.63 | 142.46 | 343 | 5.33 | 113.83 | 340 | 4.37 | 78.39 | |
| APR | 330 | 362 | 9.66 | 140.68 | 346 | 5.00 | 111.89 | 344 | 4.14 | 77.18 | |
| MAY | 333 | 364 | 9.34 | 139.89 | 348 | 4.37 | 109.88 | 346 | 3.84 | 76.17 | |
| JUN | 348 | 377 | 8.29 | 131.63 | 362 | 4.00 | 104.84 | 361 | 3.76 | 72.85 | |
| JUL | 349 | 376 | 7.65 | 130.15 | 363 | 3.95 | 104.42 | 362 | 3.75 | 72.63 | |
| AUG | 356 | 382 | 7.19 | 127.03 | 370 | 3.80 | 102.26 | 369 | 3.60 | 71.19 | |
| SEP | 367 | 393 | 6.99 | 123.17 | 380 | 3.61 | 99.11 | 380 | 3.44 | 69.09 | |
| OCT | 395 | 420 | 6.45 | 114.78 | 411 | 3.98 | 92.28 | 408 | 3.20 | 64.55 | |
| NOV | 460 | 486 | 5.65 | 99.43 | 478 | 3.87 | 79.92 | 473 | 2.91 | 55.98 | |
| DEC | 470 | 496 | 5.48 | 97.23 | 488 | 3.90 | 78.50 | 483 | 2.81 | 54.83 | |

| | ******* 75% ******* | | | | ******* 96% ******* | | |
|---|---|---|---|---|---|---|---|
| MONTH | TRUE KILL | EST KILL ($\hat{Y}$) | REL. BIAS | CV | EST KILL ($\hat{Y}$) | REL. BIAS | CV |
| JAN | 250 | 246 | -1.57 | 57.97 | 251 | 0.21 | 19.59 |
| FEB | 308 | 307 | -0.32 | 47.04 | 309 | 0.17 | 15.79 |
| MAR | 326 | 326 | -0.07 | 44.68 | 327 | 0.21 | 14.96 |
| APR | 330 | 330 | -0.15 | 44.05 | 331 | 0.23 | 14.77 |
| MAY | 333 | 332 | -0.18 | 43.57 | 334 | 0.26 | 14.63 |
| JUN | 348 | 348 | -0.10 | 41.67 | 349 | 0.26 | 13.99 |
| JUL | 349 | 349 | -0.13 | 41.53 | 350 | 0.27 | 13.95 |
| AUG | 356 | 356 | -0.12 | 40.68 | 357 | 0.27 | 13.67 |
| SEP | 367 | 366 | -0.18 | 39.43 | 368 | 0.26 | 13.26 |
| OCT | 395 | 394 | -0.13 | 36.85 | 396 | 0.26 | 12.38 |
| NOV | 460 | 459 | -0.11 | 31.98 | 461 | 0.24 | 10.75 |
| DEC | 470 | 469 | -0.14 | 31.33 | 471 | 0.24 | 10.55 |

Appendix II. Table results from small fleet (annual mortality) similations.

Species: Total kill
Number of boats: 5
Percent coverage: 25%
Number of iterations: 50
Random seed number: 8098877

| Trip | Population Day | Population Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 1123. | 1790. | 4.7 | 1723.28 | -3.73 | 36.62 | 425313.1 | 429764.3 | 655. |
| 17 | 1127. | 1396. | 4.5 | 1451.97 | 4.01 | 44.63 | 385066.4 | 388198.5 | 623. |
| 19 | 1370. | 2376. | 4.8 | 2236.98 | -5.85 | 46.34 | 1192934.6 | 1212260.4 | 1101. |
| 19 | 1136. | 2724. | 4.7 | 2571.14 | -5.61 | 24.25 | 413042.4 | 436409.3 | 660. |
| 16 | 1225. | 2299. | 4.0 | 2417.86 | 5.17 | 48.66 | 1237548.1 | 1251675.2 | 1118. |
| 18 | 1198. | 1579. | 4.5 | 1549.57 | -1.86 | 25.30 | 158702.3 | 159568.3 | 399. |
| 21 | 1226. | 2542. | 5.2 | 2475.31 | -2.62 | 42.55 | 1165676.0 | 1170123.0 | 1081. |
| 23 | 1093. | 2492. | 5.8 | 2556.20 | 2.58 | 33.49 | 692549.8 | 696671.7 | 834. |
| 17 | 1171. | 2892. | 4.1 | 2993.61 | 3.51 | 49.41 | 2031433.2 | 2041757.0 | 1428. |
| 20 | 1128. | 1847. | 4.8 | 1969.69 | 6.64 | 63.12 | 1344247.6 | 1359300.6 | 1165. |
| 18 | 1180. | 2194. | 4.7 | 2194.56 | 4.16 | 41.44 | 904651.4 | 914572.9 | 907. |

Species: Offshore spotted
Number of boats: 5
Percent coverage: 25%
Number of iterations: 50
Random seed number: 8098877

| Trip | Population Day | Population Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 1123. | 1008. | 4.7 | 908.33 | -9.89 | 42.66 | 174989.0 | 184923.4 | 430.0 |
| 17 | 1127. | 949. | 4.5 | 993.97 | 4.74 | 54.43 | 264836.1 | 266858.8 | 516.6 |
| 19 | 1370. | 1017. | 4.8 | 988.29 | -2.82 | 61.57 | 391200.2 | 392024.7 | 626.1 |
| 19 | 1136. | 1978. | 4.7 | 1832.51 | -7.36 | 27.84 | 281972.8 | 303140.3 | 550.6 |
| 16 | 1225. | 1409. | 4.0 | 1439.72 | 2.18 | 73.01 | 1057421.4 | 1058365.4 | 1028.8 |
| 18 | 1198. | 1013. | 4.5 | 978.14 | -3.44 | 35.40 | 127348.0 | 128563.0 | 358.6 |
| 21 | 1226. | 1294. | 5.2 | 1227.43 | -5.14 | 31.15 | 158086.2 | 162518.5 | 403.1 |
| 23 | 1093. | 1698. | 5.8 | 1762.20 | 3.78 | 30.72 | 268004.8 | 272126.2 | 521.7 |
| 17 | 1171. | 1655. | 4.1 | 1578.64 | -4.61 | 47.85 | 621332.6 | 627163.8 | 791.9 |
| 20 | 1128. | 804. | 4.8 | 826.16 | 2.76 | 40.13 | 103620.2 | 104111.5 | 322.7 |
| 18 | 1180. | 1282. | 4.7 | 1253.54 | 4.67 | 44.48 | 344881.1 | 349979.6 | 555.0 |

endix II, cont.

cies: Eastern spinner
ber of boats: 5
cent coverage: 25%
ber of iterations: 50
dom seed number: 8098877

| Population p | Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 1123. | 556. | 4.7 | 599.66 | 7.85 | 65.32 | 130012.4 | 131918.6 | 363.2 |
| | 1127. | 219. | 4.5 | 210.94 | -3.68 | 45.76 | 9977.5 | 10042.4 | 100.2 |
| | 1370. | 483. | 4.8 | 405.94 | -15.95 | 65.14 | 93048.1 | 98985.7 | 314.6 |
| | 1136. | 346. | 4.7 | 362.52 | 4.77 | 51.33 | 31273.6 | 31546.5 | 177.6 |
| | 1225. | 505. | 4.0 | 609.04 | 20.60 | 74.45 | 130545.6 | 141370.2 | 376.0 |
| | 1198. | 429. | 4.5 | 434.28 | 1.23 | 29.35 | 15824.6 | 15852.5 | 125.9 |
| | 1226. | 320. | 5.2 | 301.93 | -5.65 | 42.59 | 18252.3 | 18578.7 | 136.3 |
| | 1093. | 508. | 5.8 | 527.78 | 3.89 | 77.66 | 155231.7 | 155622.8 | 394.5 |
| | 1171. | 772. | 4.1 | 925.18 | 19.84 | 73.43 | 297925.4 | 321390.9 | 566.9 |
| | 1128. | 169. | 4.8 | 164.01 | -2.95 | 68.20 | 13258.3 | 13283.2 | 115.3 |
| | 1180. | 431. | 4.7 | 454.13 | 8.64 | 59.32 | 89534.9 | 93859.1 | 267.1 |

cies: Whitebelly spinner
ber of boats: 5
cent coverage: 25%
ber of iterations: 50
dom seed number: 8098877

| Population p | Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 1123. | 152. | 4.7 | 134.95 | -11.22 | 105.77 | 25555.0 | 25845.7 | 160.8 |
| | 1127. | 201. | 4.5 | 220.49 | 9.70 | 87.95 | 30870.6 | 31250.4 | 176.8 |
| | 1370. | 69. | 4.8 | 76.39 | 10.71 | 52.85 | 1275.3 | 1329.9 | 36.5 |
| | 1136. | 315. | 4.7 | 303.53 | -3.64 | 71.73 | 50915.5 | 51047.0 | 225.9 |
| | 1225. | 279. | 4.0 | 254.65 | -8.73 | 78.34 | 47184.8 | 47777.7 | 218.6 |
| | 1198. | 90. | 4.5 | 90.98 | 1.08 | 39.67 | 1273.8 | 1274.7 | 35.7 |
| | 1226. | 128. | 5.2 | 119.61 | -6.56 | 65.76 | 7013.6 | 7084.1 | 84.2 |
| | 1093. | 221. | 5.8 | 211.55 | -4.28 | 60.75 | 17936.6 | 18025.9 | 134.3 |
| | 1171. | 126. | 4.1 | 81.61 | -35.23 | 85.40 | 9609.3 | 11579.3 | 107.6 |
| | 1128. | 92. | 4.8 | 85.54 | -7.02 | 88.49 | 6586.1 | 6627.8 | 81.4 |
| | 1180. | 167. | 4.7 | 157.93 | 9.81 | 73.67 | 19822.1 | 20184.3 | 126.2 |

Appendix II, cont.

Species: Common dolphin
Number of boats: 5
Percent coverage: 25%
Number of iterations: 50
Random seed number: 8098877

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 1123. | 0. | 4.7 | 0.00 | 0.00 | -99.99 | 0.0 | 0.0 | 0.0 |
| 17 | 1127. | 0. | 4.5 | 0.00 | 0.00 | -99.99 | 0.0 | 0.0 | 0.0 |
| 19 | 1370. | 762. | 4.8 | 731.51 | -4.00 | 124.42 | 897965.7 | 898895.4 | 948.1 |
| 19 | 1136. | 34. | 4.7 | 30.13 | -11.37 | 172.92 | 3441.7 | 3456.7 | 58.8 |
| 16 | 1225. | 66. | 4.0 | 74.15 | 12.35 | 144.34 | 9008.6 | 9075.1 | 95.3 |
| 18 | 1198. | 11. | 4.5 | 12.81 | 16.48 | 161.87 | 313.8 | 317.1 | 17.8 |
| 21 | 1226. | 766. | 5.2 | 790.81 | 3.24 | 129.28 | 980024.2 | 980639.6 | 990.3 |
| 23 | 1093. | 6. | 5.8 | 4.72 | -21.35 | 173.98 | 107.3 | 109.0 | 10.4 |
| 17 | 1171. | 4. | 4.1 | 4.51 | 12.68 | 175.90 | 49.2 | 49.5 | 7.0 |
| 20 | 1128. | 770. | 4.8 | 881.55 | 14.49 | 152.77 | 1371380.0 | 1383822.6 | 1176.4 |
| 18 | 1180. | 242. | 4.7 | 253.02 | 9.60 | 103.55 | 326229.1 | 327636.5 | 330.4 |

Species: Total kill
Number of boats: 5
Percent coverage: 50%
Number of iterations: 50
Random seed number: 3934762

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 18 | 1101. | 3018. | 8.9 | 2908.67 | -3.62 | 25.86 | 597009.1 | 608963.2 | 780.4 |
| 23 | 1224. | 2608. | 11.5 | 2678.13 | 2.69 | 26.57 | 475143.2 | 480061.7 | 692.9 |
| 22 | 1098. | 2210. | 11.1 | 2225.81 | 0.72 | 28.20 | 388076.7 | 388326.7 | 623.2 |
| 20 | 1195. | 2252. | 10.0 | 2114.42 | -6.11 | 23.30 | 256440.8 | 275368.5 | 524.8 |
| 20 | 1140. | 1696. | 10.0 | 1642.64 | -3.15 | 30.74 | 268890.9 | 271738.0 | 521.3 |
| 18 | 1199. | 2950. | 9.2 | 3060.57 | 3.75 | 20.34 | 347932.6 | 360157.6 | 600.1 |
| 16 | 1215. | 2617. | 8.0 | 2609.35 | -0.29 | 28.45 | 554297.1 | 554355.6 | 744.6 |
| 18 | 978. | 1061. | 8.8 | 1041.21 | -1.87 | 34.52 | 133756.3 | 134147.9 | 366.3 |
| 21 | 1013. | 2234. | 10.3 | 2356.05 | 5.46 | 26.74 | 342072.1 | 356968.3 | 597.5 |
| 18 | 1108. | 3007. | 9.1 | 2907.59 | -3.31 | 22.88 | 463307.7 | 473189.2 | 687.9 |
| 19 | 1127. | 2365. | 9.7 | 2354.44 | 3.10 | 26.76 | 382692.6 | 390327.7 | 613.9 |

endix II, cont.

cies: Offshore spotted
ber of boats: 5
cent coverage: 50%
ber of iterations: 50
dom seed number: 3934762

| Population p Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|
| 1101. | 1210. | 8.9 | 1223.12 | 1.08 | 29.23 | 124901.9 | 125074.0 | 353.7 |
| 1224. | 1260. | 11.5 | 1248.75 | -0.89 | 26.70 | 113067.2 | 113193.7 | 336.4 |
| 1098. | 1556. | 11.1 | 1576.96 | 1.35 | 31.18 | 234935.6 | 235374.7 | 485.2 |
| 1195. | 1808. | 10.0 | 1681.55 | -6.99 | 26.71 | 217255.3 | 233243.9 | 483.0 |
| 1140. | 477. | 10.0 | 470.13 | -1.44 | 18.15 | 7445.8 | 7493.0 | 86.6 |
| 1199. | 1509. | 9.2 | 1630.32 | 8.04 | 20.93 | 85042.0 | 99759.5 | 315.8 |
| 1215. | 1713. | 8.0 | 1697.43 | -0.91 | 38.80 | 441545.4 | 441787.9 | 664.7 |
| 978. | 772. | 8.8 | 754.07 | -2.32 | 40.67 | 98274.4 | 98595.9 | 314.0 |
| 1013. | 980. | 10.3 | 971.42 | -0.88 | 20.09 | 38705.0 | 38778.7 | 196.9 |
| 1108. | 1943. | 9.1 | 1903.15 | -2.05 | 29.61 | 329297.8 | 330886.0 | 575.2 |
| 1127. | 1323. | 9.7 | 1315.69 | 2.60 | 28.21 | 169047.0 | 172418.7 | 381.1 |

cies: Eastern spinner
ber of boats: 5
cent coverage: 50%
ber of iterations: 50
dom seed number: 3934762

| Population p Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|
| 1101. | 737. | 8.9 | 756.58 | 2.66 | 39.52 | 84454.3 | 84837.9 | 291.3 |
| 1224. | 315. | 11.5 | 278.09 | -11.72 | 28.85 | 6896.8 | 8259.4 | 90.9 |
| 1098. | 414. | 11.1 | 408.35 | -1.36 | 53.48 | 48995.7 | 49027.6 | 221.4 |
| 1195. | 160. | 10.0 | 157.55 | -1.53 | 40.18 | 4127.7 | 4133.7 | 64.3 |
| 1140. | 336. | 10.0 | 313.59 | -6.67 | 57.66 | 37027.7 | 37530.1 | 193.7 |
| 1199. | 982. | 9.2 | 950.15 | -3.24 | 30.69 | 89805.4 | 90820.0 | 301.4 |
| 1215. | 512. | 8.0 | 522.39 | 2.03 | 33.82 | 29882.7 | 29990.6 | 173.2 |
| 978. | 161. | 8.8 | 159.22 | -1.10 | 34.43 | 3069.0 | 3072.1 | 55.4 |
| 1013. | 274. | 10.3 | 282.23 | 3.00 | 30.47 | 6901.5 | 6969.1 | 83.5 |
| 1108. | 684. | 9.1 | 635.38 | -7.11 | 32.38 | 46693.5 | 49057.5 | 221.5 |
| 1127. | 457. | 9.7 | 446.35 | 4.04 | 38.15 | 35785.4 | 36369.8 | 169.7 |

Appendix II, cont.

Species: Whitebelly spinner
Number of boats: 5
Percent coverage: 50%
Number of iterations: 50
Random seed number: 3934762

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 18 | 1101. | 213. | 8.9 | 182.26 | -14.43 | 57.74 | 14180.4 | 15125.5 | 123.0 |
| 23 | 1224. | 187. | 11.5 | 197.90 | 5.83 | 44.57 | 6827.7 | 6946.6 | 83.3 |
| 22 | 1098. | 182. | 11.1 | 183.18 | 0.65 | 35.86 | 4257.4 | 4258.8 | 65.3 |
| 20 | 1195. | 231. | 10.0 | 221.56 | -4.09 | 48.17 | 12291.2 | 12380.2 | 111.3 |
| 20 | 1140. | 87. | 10.0 | 80.57 | -7.39 | 49.24 | 1794.1 | 1835.4 | 42.8 |
| 18 | 1199. | 103. | 9.2 | 108.29 | 5.13 | 42.23 | 1864.1 | 1892.1 | 43.5 |
| 16 | 1215. | 300. | 8.0 | 303.86 | 1.29 | 54.33 | 26553.2 | 26568.1 | 163.0 |
| 18 | 978. | 102. | 8.8 | 102.07 | 0.07 | 78.87 | 6471.3 | 6471.3 | 80.4 |
| 21 | 1013. | 137. | 10.3 | 130.76 | -4.55 | 40.27 | 3004.9 | 3043.9 | 55.2 |
| 18 | 1108. | 219. | 9.1 | 215.55 | -1.58 | 41.66 | 8311.7 | 8323.6 | 91.2 |
| 19 | 1127. | 176. | 9.7 | 172.60 | 4.50 | 49.29 | 8555.6 | 8684.6 | 85.9 |

Species: Common dolphin
Number of boats: 5
Percent coverage: 50%
Number of iterations: 50
Random seed number: 3934762

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 18 | 1101. | 796. | 8.9 | 684.34 | -14.03 | 73.75 | 332130.9 | 344598.9 | 587.0 |
| 23 | 1224. | 768. | 11.5 | 871.63 | 13.49 | 69.24 | 271997.2 | 282736.3 | 531.7 |
| 22 | 1098. | 0. | 11.1 | 0.00 | 0.00 | -99.99 | 0.0 | 0.0 | 0.0 |
| 20 | 1195. | 34. | 10.0 | 33.76 | -0.69 | 101.08 | 1181.0 | 1181.1 | 34.4 |
| 20 | 1140. | 776. | 10.0 | 757.57 | -2.38 | 68.49 | 282139.7 | 282479.5 | 531.5 |
| 18 | 1199. | 0. | 9.2 | 0.00 | 0.00 | -99.99 | 0.0 | 0.0 | 0.0 |
| 16 | 1215. | 55. | 8.0 | 49.72 | -9.60 | 96.36 | 2780.6 | 2808.5 | 53.0 |
| 18 | 978. | 8. | 8.8 | 7.40 | -7.47 | 77.39 | 38.0 | 38.3 | 6.2 |
| 21 | 1013. | 768. | 10.3 | 896.90 | 16.78 | 74.16 | 307758.7 | 324373.7 | 569.5 |
| 18 | 1108. | 55. | 9.1 | 49.17 | -10.61 | 95.04 | 2698.2 | 2732.2 | 52.3 |
| 19 | 1127. | 326. | 9.7 | 335.05 | 7.51 | 45.55 | 120072.4 | 124094.9 | 236.6 |

endix II, cont.

cies: Total kill
ber of boats: 5
cent coverage: 75%
ber of iterations: 50
dom seed number: 9098876

| Population p | Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 1286. | 2218. | 15.8 | 2242.27 | 1.09 | 11.92 | 69256.9 | 69846.1 | 264.3 |
| ) | 1200. | 3271. | 15.1 | 3248.76 | -0.68 | 14.25 | 216896.8 | 217391.5 | 466.3 |
| | 966. | 2153. | 16.3 | 2187.49 | 1.60 | 19.41 | 173480.7 | 174670.5 | 417.9 |
| ) | 1217. | 2692. | 14.3 | 2739.11 | 1.75 | 15.02 | 161340.7 | 163560.2 | 404.4 |
| | 1297. | 1132. | 15.7 | 1123.35 | -0.76 | 11.33 | 16368.4 | 16443.3 | 128.2 |
| | 1279. | 1272. | 18.0 | 1262.43 | -0.75 | 12.16 | 23836.7 | 23928.2 | 154.7 |
| | 1233. | 1552. | 13.6 | 1555.97 | 0.26 | 10.61 | 27118.8 | 27134.6 | 164.7 |
| ) | 1254. | 1481. | 14.2 | 1496.76 | 1.06 | 15.11 | 49840.8 | 50089.1 | 223.8 |
| | 1084. | 1417. | 13.7 | 1411.99 | -0.35 | 7.11 | 10131.4 | 10156.5 | 100.8 |
| ) | 1007. | 1753. | 14.2 | 1784.62 | 1.80 | 11.33 | 38457.7 | 39457.2 | 198.6 |
| ) | 1182. | 1894. | 15.1 | 1905.27 | 1.01 | 12.83 | 78672.9 | 79267.7 | 252.4 |

cies: Offshore spotter
ıber of boats: 5
cent coverage: 75%
ıber of iterations: 50
ıdom seed number: 9098876

| Population p | Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 1286. | 1648. | 15.8 | 1669.34 | 1.29 | 14.17 | 54095.4 | 54550.8 | 233.6 |
| ) | 1200. | 1757. | 15.1 | 1743.75 | -0.75 | 15.38 | 72826.7 | 73002.3 | 270.2 |
| | 966. | 927. | 16.3 | 939.93 | 1.40 | 20.78 | 36935.1 | 37102.4 | 192.6 |
| ) | 1217. | 1548. | 14.3 | 1588.90 | 2.64 | 13.20 | 40102.3 | 41775.0 | 204.4 |
| | 1297. | 785. | 15.7 | 776.88 | -1.03 | 13.31 | 10857.1 | 10923.1 | 104.5 |
| | 1279. | 954. | 18.0 | 948.58 | -0.57 | 13.95 | 17670.5 | 17699.9 | 133.0 |
| | 1233. | 1070. | 13.6 | 1078.53 | 0.80 | 14.96 | 25550.1 | 25622.8 | 160.1 |
| ) | 1254. | 831. | 14.2 | 853.67 | 2.73 | 21.86 | 32483.7 | 32997.5 | 181.7 |
| | 1084. | 847. | 13.7 | 856.12 | 1.08 | 7.70 | 4168.8 | 4251.9 | 65.2 |
| ) | 1007. | 1358. | 14.2 | 1380.39 | 1.65 | 12.82 | 29797.2 | 30298.6 | 174.1 |
| ) | 1182. | 1172. | 15.1 | 1183.61 | 1.39 | 14.81 | 32448.7 | 32822.4 | 171.9 |

Appendix II, cont.

Species: Eastern spinner
Number of boats: 5
Percent coverage: 75%
Number of iterations: 50
Random seed number: 9098876

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 21 | 1286. | 312. | 15.8 | 312.77 | 0.25 | 15.37 | 2298.5 | 2299.1 | 47.9 |
| 20 | 1200. | 454. | 15.1 | 463.12 | 2.01 | 30.27 | 18800.3 | 18883.4 | 137.4 |
| 22 | 966. | 359. | 16.3 | 365.01 | 1.67 | 34.76 | 15532.6 | 15568.7 | 124.8 |
| 19 | 1217. | 207. | 14.3 | 194.98 | -5.81 | 18.90 | 1386.6 | 1531.0 | 39.1 |
| 21 | 1297. | 188. | 15.7 | 189.99 | 1.06 | 14.43 | 732.5 | 736.5 | 27.1 |
| 24 | 1279. | 180. | 18.0 | 177.80 | -1.22 | 15.95 | 819.9 | 824.8 | 28.7 |
| 18 | 1233. | 322. | 13.6 | 321.73 | -0.08 | 13.91 | 2006.7 | 2006.7 | 44.8 |
| 19 | 1254. | 550. | 14.2 | 545.27 | -0.86 | 16.95 | 8666.4 | 8688.7 | 93.2 |
| 18 | 1084. | 336. | 13.7 | 327.59 | -2.50 | 14.55 | 2318.6 | 2389.4 | 48.9 |
| 19 | 1007. | 194. | 14.2 | 199.53 | 2.85 | 14.59 | 770.7 | 801.2 | 28.3 |
| 20 | 1182. | 310. | 15.1 | 309.78 | 1.83 | 18.97 | 5333.3 | 5373.0 | 62.0 |

Species: Whitebelly spinner
Number of boats: 5
Percent coverage: 75%
Number of iterations: 50
Random seed number: 9098876

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 21 | 1286. | 186. | 15.8 | 186.93 | 0.50 | 17.64 | 1075.1 | 1075.9 | 32.8 |
| 20 | 1200. | 197. | 15.1 | 198.88 | 0.95 | 19.37 | 1452.0 | 1455.5 | 38.2 |
| 22 | 966. | 69. | 16.3 | 74.67 | 8.22 | 41.15 | 774.1 | 806.3 | 28.4 |
| 19 | 1217. | 146. | 14.3 | 158.44 | 8.52 | 26.69 | 1363.6 | 1518.2 | 39.0 |
| 21 | 1297. | 122. | 15.7 | 119.21 | -2.29 | 24.41 | 879.2 | 887.0 | 29.8 |
| 24 | 1279. | 103. | 18.0 | 99.22 | -3.67 | 19.56 | 391.4 | 405.8 | 20.1 |
| 18 | 1233. | 125. | 13.6 | 120.30 | -3.76 | 23.83 | 865.4 | 887.5 | 29.8 |
| 19 | 1254. | 52. | 14.2 | 49.70 | -4.43 | 17.67 | 79.2 | 84.5 | 9.2 |
| 18 | 1084. | 187. | 13.7 | 178.61 | -4.49 | 36.21 | 4515.3 | 4585.7 | 67.7 |
| 19 | 1007. | 138. | 14.2 | 136.31 | -1.22 | 19.25 | 702.8 | 705.6 | 26.6 |
| 20 | 1182. | 132. | 15.1 | 132.23 | 3.81 | 24.58 | 1209.8 | 1241.2 | 32.2 |

endix II, cont.

cies: Common dolphin
ber of boats: 5
cent coverage: 75%
ber of iterations: 50
dom seed number: 9098876

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 1286. | 0. | 15.8 | 0.00 | 0.00 | -99.99 | 0.0 | 0.0 | 0.0 |
| | 1200. | 796. | 15.1 | 777.07 | -2.38 | 40.63 | 104219.4 | 104577.6 | 323.4 |
| | 966. | 768. | 16.3 | 777.85 | 1.28 | 39.38 | 91366.0 | 91463.1 | 302.4 |
| | 1217. | 764. | 14.3 | 769.72 | 0.75 | 38.70 | 87392.5 | 87425.3 | 295.7 |
| | 1297. | 8. | 15.7 | 7.10 | -11.20 | 65.67 | 26.8 | 27.6 | 5.3 |
| | 1279. | 6. | 18.0 | 6.86 | 14.41 | 49.24 | 8.0 | 8.7 | 3.0 |
| | 1233. | 0. | 13.6 | 0.00 | 0.00 | -99.99 | 0.0 | 0.0 | 0.0 |
| | 1254. | 4. | 14.2 | 3.97 | -0.80 | 59.75 | 5.7 | 5.7 | 2.4 |
| | 1084. | 4. | 13.7 | 4.21 | 5.28 | 54.29 | 4.7 | 4.7 | 2.2 |
| | 1007. | 34. | 14.2 | 38.57 | 13.43 | 53.55 | 310.7 | 331.6 | 18.2 |
| | 1182. | 238. | 15.1 | 238.54 | 4.95 | 20.12 | 28333.4 | 28384.4 | 95.2 |

ecies: Total kill
ıber of boats: 10
rcent coverage: 25%
ıber of iterations: 50
ıdom seed number: 34564322

| .p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 2421. | 2797. | 9.2 | 2736.74 | -2.15 | 24.66 | 472094.3 | 475725.7 | 689.7 |
| | 2506. | 4760. | 9.3 | 4611.62 | -3.12 | 32.30 | 2341406.2 | 2363422.7 | 1537.3 |
| | 2393. | 4767. | 9.6 | 4834.05 | 1.41 | 38.18 | 3308837.7 | 3313333.7 | 1820.3 |
| | 2297. | 5079. | 8.7 | 5055.66 | -0.46 | 29.11 | 2186036.2 | 2186581.0 | 1478.7 |
| | 2439. | 2454. | 9.2 | 2629.76 | 7.16 | 31.67 | 573168.6 | 604061.3 | 777.2 |
| | 2269. | 4625. | 9.5 | 4534.36 | -1.96 | 26.20 | 1460018.4 | 1468233.2 | 1211.7 |
| | 2120. | 3712. | 8.2 | 3485.32 | -6.11 | 25.85 | 869238.7 | 920621.8 | 959.5 |
| | 2638. | 4072. | 10.4 | 3785.51 | -7.04 | 28.51 | 1265823.1 | 1347897.9 | 1161.0 |
| | 2280. | 4364. | 9.4 | 4301.35 | -1.44 | 31.46 | 1881566.0 | 1885490.6 | 1373.1 |
| | 2103. | 2666. | 8.6 | 2624.72 | -1.55 | 33.80 | 810070.7 | 811774.6 | 901.0 |
| | 2347. | 3930. | 9.2 | 3859.91 | 3.24 | 30.17 | 1516826.0 | 1537714.2 | 1191.0 |

Appendix II, cont.

Species: Offshore spotted
Number of boats: 10
Percent coverage: 25%
Number of iterations: 50
Random seed number: 34564322

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 37 | 2421. | 1828. | 9.2 | 1778.12 | -2.73 | 29.10 | 280519.3 | 283007.2 | 532.0 |
| 37 | 2506. | 3280. | 9.3 | 3147.38 | -4.04 | 42.74 | 1947286.2 | 1964873.7 | 1401.7 |
| 39 | 2393. | 2980. | 9.6 | 3052.05 | 2.42 | 48.30 | 2066184.4 | 2071374.9 | 1439.2 |
| 35 | 2297. | 2834. | 8.7 | 2850.76 | 0.59 | 45.25 | 1644457.5 | 1644738.4 | 1282.5 |
| 38 | 2439. | 1845. | 9.2 | 2005.23 | 8.68 | 35.89 | 412819.6 | 438492.6 | 662.2 |
| 39 | 2269. | 2771. | 9.5 | 2824.96 | 1.95 | 30.22 | 698136.7 | 701048.1 | 837.3 |
| 32 | 2120. | 2324. | 8.2 | 2294.54 | -1.27 | 26.15 | 368569.3 | 369437.0 | 607.8 |
| 42 | 2638. | 2243. | 10.4 | 2086.22 | -6.99 | 28.23 | 376414.1 | 400994.0 | 633.2 |
| 37 | 2280. | 3117. | 9.4 | 3070.47 | -1.49 | 36.89 | 1320371.1 | 1322536.5 | 1150.0 |
| 34 | 2103. | 1756. | 8.6 | 1687.68 | -3.89 | 42.97 | 564667.4 | 569335.4 | 754.5 |
| 37 | 2347. | 2498. | 9.2 | 2479.74 | 3.41 | 36.57 | 967942.6 | 976583.7 | 930.1 |

Species: Easter spinner
Number of boats: 10
Percent coverage: 25%
Number of iterations: 50
Random seed number: 34564322

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 37 | 2421. | 479. | 9.2 | 457.25 | -4.54 | 27.15 | 16444.9 | 16917.8 | 130.1 |
| 37 | 2506. | 998. | 9.3 | 1015.41 | 1.74 | 36.24 | 130478.9 | 130782.0 | 361.6 |
| 39 | 2393. | 1250. | 9.6 | 1207.33 | -3.41 | 45.18 | 317108.5 | 318928.9 | 564.7 |
| 35 | 2297. | 1422. | 8.7 | 1445.93 | 1.68 | 37.98 | 291166.6 | 291739.1 | 540.1 |
| 38 | 2439. | 346. | 9.2 | 328.42 | -5.08 | 33.31 | 12973.4 | 13282.6 | 115.3 |
| 39 | 2269. | 1127. | 9.5 | 1155.24 | 2.51 | 52.43 | 348349.0 | 349146.4 | 590.9 |
| 32 | 2120. | 652. | 8.2 | 624.70 | -4.19 | 40.19 | 67917.7 | 68663.2 | 262.0 |
| 42 | 2638. | 587. | 10.4 | 605.44 | 3.14 | 29.17 | 28971.0 | 29311.1 | 171.2 |
| 37 | 2280. | 752. | 9.4 | 757.30 | 0.71 | 55.63 | 175003.1 | 175031.2 | 418.4 |
| 34 | 2103. | 663. | 8.6 | 700.41 | 5.64 | 50.50 | 110712.7 | 112112.2 | 334.8 |
| 37 | 2347. | 828. | 9.2 | 829.74 | 3.26 | 40.78 | 149912.6 | 150591.4 | 348.9 |

endix II, cont.

cies: Whitebelly spinner
ber of boats: 10
cent coverage: 25%
ber of iterations: 50
dom seed number: 34564322

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 2421. | 388. | 9.2 | 418.89 | 7.96 | 55.78 | 45889.1 | 46843.4 | 216.4 |
| | 2506. | 345. | 9.3 | 324.03 | -6.08 | 70.06 | 57977.0 | 58416.8 | 241.7 |
| | 2393. | 337. | 9.6 | 375.26 | 11.35 | 63.39 | 44165.9 | 45629.8 | 213.6 |
| | 2297. | 347. | 8.7 | 319.05 | -8.05 | 62.00 | 45501.8 | 46282.9 | 215.1 |
| | 2439. | 230. | 9.2 | 262.95 | 14.33 | 79.29 | 32169.7 | 33255.4 | 182.4 |
| | 2269. | 348. | 9.5 | 315.28 | -9.40 | 57.18 | 38530.8 | 39601.8 | 199.0 |
| | 2120. | 330. | 8.2 | 273.23 | -17.20 | 50.47 | 24516.2 | 27739.0 | 166.6 |
| | 2638. | 378. | 10.4 | 338.37 | -10.48 | 51.84 | 36824.3 | 38395.1 | 195.9 |
| | 2280. | 345. | 9.4 | 333.92 | -3.21 | 71.11 | 60062.1 | 60184.8 | 245.3 |
| | 2103. | 164. | 8.6 | 155.60 | -5.12 | 65.30 | 11397.1 | 11467.6 | 107.1 |
| | 2347. | 321. | 9.2 | 311.66 | 9.32 | 62.64 | 39703.4 | 40781.7 | 198.3 |

ecies: Common dolphin
ıber of boats: 10
rcent coverage: 25%
ıber of iterations: 50
ıdom seed number: 34564322

| .p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 2421. | 42. | 9.2 | 28.74 | -31.57 | 124.95 | 2578.1 | 2753.9 | 52.5 |
| 7 | 2506. | 59. | 9.3 | 39.96 | -32.26 | 138.98 | 6361.1 | 6723.4 | 82.0 |
| 9 | 2393. | 89. | 9.6 | 77.25 | -13.20 | 132.61 | 13791.0 | 13929.1 | 118.0 |
| 5 | 2297. | 55. | 8.7 | 26.14 | -52.48 | 130.48 | 4317.4 | 5150.4 | 71.8 |
| 3 | 2439. | 12. | 9.2 | 12.93 | 7.78 | 101.63 | 147.9 | 148.7 | 12.2 |
| 9 | 2269. | 11. | 9.5 | 12.36 | 12.36 | 158.51 | 302.2 | 304.0 | 17.4 |
| 2 | 2120. | 21. | 8.2 | 19.02 | -9.44 | 97.90 | 418.7 | 422.7 | 20.6 |
| 2 | 2638. | 770. | 10.4 | 666.00 | -13.51 | 113.90 | 758337.6 | 769154.1 | 877.0 |
| 7 | 2280. | 74. | 9.4 | 67.39 | -8.93 | 122.21 | 8134.8 | 8178.5 | 90.4 |
| 4 | 2103. | 34. | 8.6 | 31.79 | -6.51 | 171.25 | 3385.4 | 3390.3 | 58.2 |
| 7 | 2347. | 117. | 9.2 | 98.16 | 18.80 | 129.24 | 79777.4 | 81015.5 | 140.0 |

Appendix II, cont.

Species: Total kill
Number of boats: 10
Percent coverage: 50%
Number of iterations: 50
Random seed number: 9875343

| Trip | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 43 | 2527. | 3781. | 21.8 | 3756.61 | -0.65 | 11.85 | 199998.0 | 200593.0 | 447.9 |
| 35 | 2311. | 4270. | 17.5 | 4232.40 | -0.88 | 13.69 | 340414.5 | 341828.3 | 584.7 |
| 38 | 2130. | 3327. | 19.0 | 3225.11 | -3.06 | 22.80 | 564872.2 | 575253.6 | 758.5 |
| 38 | 2108. | 4582. | 19.0 | 4483.21 | -2.16 | 14.83 | 452025.7 | 461784.9 | 679.5 |
| 39 | 2176. | 3749. | 19.3 | 3756.20 | 0.19 | 16.01 | 360080.0 | 360131.8 | 600.1 |
| 40 | 2240. | 3228. | 20.0 | 3025.78 | -6.26 | 23.97 | 557644.8 | 598536.1 | 773.7 |
| 37 | 2212. | 4734. | 18.4 | 4557.72 | -3.72 | 11.82 | 282189.0 | 313263.6 | 559.7 |
| 35 | 2196. | 3544. | 17.7 | 3720.29 | 4.97 | 20.06 | 474521.8 | 505598.4 | 711.1 |
| 42 | 2457. | 4606. | 21.1 | 4553.73 | -1.13 | 14.46 | 440883.8 | 443616.1 | 666.0 |
| 36 | 2253. | 4040. | 18.1 | 4123.10 | 2.06 | 18.54 | 554134.6 | 561040.1 | 749.0 |
| 38 | 2261. | 3986. | 19.2 | 3943.41 | 2.51 | 16.80 | 422676.4 | 436164.6 | 653.0 |

Species: Offshore spotted
Number of boats: 10
Percent coverage: 50%
Number of iterations: 50
Random seed number: 9875343

| Trip | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 43 | 2527. | 2352. | 21.8 | 2336.25 | -0.67 | 11.13 | 68268.1 | 68516.1 | 261.8 |
| 35 | 2311. | 2712. | 17.5 | 2677.77 | -1.26 | 15.91 | 184997.0 | 186168.9 | 431.5 |
| 38 | 2130. | 2545. | 19.0 | 2469.37 | -2.97 | 27.24 | 474743.0 | 480462.3 | 693.2 |
| 38 | 2108. | 2867. | 19.0 | 2771.61 | -3.33 | 16.95 | 227008.3 | 236107.1 | 485.9 |
| 39 | 2176. | 2670. | 19.3 | 2709.60 | 1.48 | 18.84 | 251580.9 | 253149.0 | 503.1 |
| 40 | 2240. | 1871. | 20.0 | 1825.63 | -2.42 | 20.44 | 144207.1 | 146265.5 | 382.4 |
| 37 | 2212. | 3191. | 18.4 | 3026.02 | -5.17 | 14.54 | 188115.2 | 215334.2 | 464.0 |
| 35 | 2196. | 2681. | 17.7 | 2809.50 | 4.79 | 24.13 | 402042.1 | 418554.0 | 647.0 |
| 42 | 2457. | 3271. | 21.1 | 3276.86 | 0.18 | 16.48 | 290502.2 | 290536.6 | 539.0 |
| 36 | 2253. | 2789. | 18.1 | 2862.71 | 2.64 | 20.21 | 312151.7 | 317585.2 | 563.5 |
| 38 | 2261. | 2695. | 19.2 | 2676.53 | 2.49 | 18.59 | 254361.5 | 261267.9 | 497.1 |

endix II, cont.

cies: Eastern spinner
ber of boats: 10
cent coverage: 50%
ber of iterations: 50
dom seed number: 9875343

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| | 2527. | 1047. | 21.8 | 1022.14 | -2.37 | 27.98 | 85194.2 | 85812.0 | 292.9 |
| | 2311. | 862. | 17.5 | 858.24 | -0.44 | 22.03 | 36032.3 | 36046.4 | 189.9 |
| | 2130. | 417. | 19.0 | 404.86 | -2.91 | 20.54 | 7189.3 | 7336.7 | 85.7 |
| | 2108. | 1006. | 19.0 | 1008.79 | 0.28 | 23.49 | 55833.2 | 55841.0 | 236.3 |
| | 2176. | 514. | 19.3 | 505.50 | -1.65 | 28.63 | 21589.9 | 21662.2 | 147.2 |
| ) | 2240. | 349. | 20.0 | 355.64 | 1.90 | 25.85 | 8097.7 | 8141.8 | 90.2 |
| | 2212. | 934. | 18.4 | 963.60 | 3.17 | 21.67 | 40096.4 | 40972.3 | 202.4 |
| ; | 2196. | 461. | 17.7 | 474.07 | 2.84 | 18.03 | 6736.5 | 6907.4 | 83.1 |
| | 2457. | 820. | 21.1 | 759.80 | -7.34 | 25.92 | 41537.0 | 45161.4 | 212.5 |
| ; | 2253. | 851. | 18.1 | 842.55 | -0.99 | 31.56 | 72082.6 | 72154.1 | 268.6 |
| ; | 2261. | 726. | 19.2 | 719.52 | 2.39 | 24.57 | 37438.9 | 38003.5 | 180.9 |

cies: Whitebelly spinner
ber of boats: 10
cent coverage: 50%
ber of iterations: 50
dom seed number: 9875343

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| ; | 2527. | 276. | 21.8 | 291.99 | 5.79 | 30.08 | 6635.3 | 6891.0 | 83.0 |
| ; | 2311. | 281. | 17.5 | 291.52 | 3.74 | 23.49 | 4247.3 | 4358.0 | 66.0 |
| ; | 2130. | 263. | 19.0 | 258.77 | -1.61 | 43.63 | 13148.2 | 13166.1 | 114.7 |
| ; | 2108. | 296. | 19.0 | 253.03 | -14.52 | 43.08 | 14414.5 | 16260.6 | 127.5 |
| ) | 2176. | 220. | 19.3 | 222.02 | 0.92 | 40.82 | 8062.3 | 8066.4 | 89.8 |
| ) | 2240. | 211. | 20.0 | 213.24 | 1.06 | 29.17 | 3783.3 | 3788.3 | 61.5 |
| ' | 2212. | 446. | 18.4 | 402.97 | -9.65 | 32.87 | 19641.8 | 21493.7 | 146.6 |
| ; | 2196. | 289. | 17.7 | 307.28 | 6.33 | 32.38 | 8422.0 | 8756.3 | 93.6 |
| ; | 2457. | 408. | 21.1 | 420.51 | 3.07 | 39.50 | 25812.5 | 25968.9 | 161.1 |
| ; | 2253. | 244. | 18.1 | 253.66 | 3.96 | 26.41 | 4058.6 | 4151.8 | 64.4 |
| ; | 2261. | 293. | 19.2 | 291.50 | 5.06 | 34.14 | 10822.6 | 11290.1 | 100.8 |

Appendix II, cont.

Species: Common dolphin
Number of boats: 10
Percent coverage: 50%
Number of iterations: 50
Random seed number: 9875343

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 43 | 2527. | 17. | 21.8 | 16.86 | -0.80 | 69.72 | 140.5 | 140.5 | 11.9 |
| 35 | 2311. | 19. | 17.5 | 16.50 | -13.15 | 61.66 | 131.0 | 137.2 | 11.7 |
| 38 | 2130. | 72. | 19.0 | 62.84 | -12.73 | 72.90 | 2670.8 | 2754.7 | 52.5 |
| 38 | 2108. | 34. | 19.0 | 36.48 | 7.28 | 100.75 | 1167.3 | 1173.4 | 34.3 |
| 39 | 2176. | 14. | 19.3 | 11.87 | -15.21 | 71.82 | 96.6 | 101.1 | 10.1 |
| 40 | 2240. | 770. | 20.0 | 605.96 | -21.30 | 75.82 | 313918.4 | 340829.2 | 583.8 |
| 37 | 2212. | 8. | 18.4 | 9.00 | 12.46 | 101.89 | 65.4 | 66.4 | 8.2 |
| 35 | 2196. | 68. | 17.7 | 82.40 | 21.17 | 75.81 | 2450.1 | 2657.4 | 51.6 |
| 42 | 2457. | 6. | 21.1 | 5.94 | -0.98 | 100.45 | 36.3 | 36.3 | 6.0 |
| 36 | 2253. | 47. | 18.1 | 54.50 | 15.96 | 76.93 | 1251.0 | 1307.2 | 36.2 |
| 38 | 2261. | 105. | 19.2 | 90.23 | 12.10 | 80.77 | 32192.7 | 34920.4 | 80.6 |

Species: Total kill
Number of boats: 10
Percent coverage: 75%
Number of iterations: 50
Random seed number: 4565432

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 38 | 2473. | 3834. | 28.5 | 3784.76 | -1.28 | 10.52 | 160177.8 | 162602.1 | 403.2 |
| 40 | 2259. | 4364. | 30.2 | 4404.14 | 0.92 | 10.10 | 192814.6 | 194425.9 | 440.9 |
| 40 | 2572. | 3934. | 30.0 | 3972.41 | 0.98 | 11.48 | 202605.4 | 204080.7 | 451.8 |
| 38 | 2241. | 4734. | 28.3 | 4752.50 | 0.39 | 9.01 | 181695.7 | 182038.0 | 426.7 |
| 41 | 2210. | 4490. | 30.8 | 4466.28 | -0.53 | 10.48 | 220737.1 | 221299.8 | 470.4 |
| 38 | 2387. | 5340. | 28.4 | 5413.77 | 1.38 | 10.65 | 317849.3 | 323291.0 | 568.6 |
| 36 | 2589. | 3522. | 27.0 | 3633.09 | 3.15 | 11.62 | 155292.7 | 167634.7 | 409.4 |
| 41 | 2602. | 3998. | 30.8 | 3948.87 | -1.23 | 10.59 | 176741.6 | 179155.5 | 423.3 |
| 38 | 2277. | 3212. | 28.3 | 3301.77 | 2.79 | 10.92 | 115015.8 | 123075.0 | 350.8 |
| 36 | 2284. | 4510. | 27.1 | 4480.24 | -0.66 | 9.44 | 180335.7 | 181221.1 | 425.7 |
| 38 | 2389. | 4194. | 28.9 | 4215.78 | 1.33 | 10.48 | 190326.5 | 193882.4 | 437.1 |

endix II,cies: Offshore spotted

ber of boats: 10
cent coverage: 75%
ber of iterations: 50
dom seed number: 4565432

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 2473. | 2657. | 28.5 | 2625.40 | -1.19 | 14.06 | 138460.7 | 139459.4 | 373.4 |
| ) | 2259. | 2944. | 30.2 | 2952.00 | 0.27 | 10.55 | 96364.7 | 96428.7 | 310.5 |
| ) | 2572. | 2163. | 30.0 | 2179.12 | 0.75 | 11.19 | 58320.1 | 58580.0 | 242.0 |
| 3 | 2241. | 3024. | 28.3 | 3013.89 | -0.33 | 9.43 | 81224.2 | 81326.4 | 285.2 |
| . | 2210. | 2970. | 30.8 | 2979.73 | 0.33 | 13.10 | 151268.1 | 151362.8 | 389.1 |
| 3 | 2387. | 2702. | 28.4 | 2733.41 | 1.16 | 15.05 | 164376.4 | 165362.8 | 406.6 |
| 5 | 2589. | 1914. | 27.0 | 1981.22 | 3.51 | 11.15 | 41027.1 | 45546.1 | 213.4 |
| L | 2602. | 2636. | 30.8 | 2640.33 | 0.16 | 12.90 | 115586.0 | 115604.7 | 340.0 |
| 3 | 2277. | 1785. | 28.3 | 1760.23 | -1.39 | 11.87 | 44317.2 | 44930.6 | 212.0 |
| 5 | 2284. | 2064. | 27.1 | 2027.70 | -1.76 | 10.27 | 43572.5 | 44889.9 | 211.9 |
| 3 | 2389. | 2486. | 28.9 | 2489.30 | 1.09 | 11.96 | 93451.7 | 94349.1 | 298.4 |

ecies: Eastern spinner

nber of boats: 10
rcent coverage: 75%
nber of iterations: 50
ndom seed number: 4565432

| ip | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 2473. | 646. | 28.5 | 628.12 | -2.77 | 8.91 | 2992.6 | 3312.5 | 57.6 |
| ) | 2259. | 772. | 30.2 | 792.52 | 2.66 | 17.71 | 18262.2 | 18683.1 | 136.7 |
| ) | 2572. | 679. | 30.0 | 689.73 | 1.58 | 17.69 | 14306.5 | 14421.6 | 120.1 |
| 3 | 2241. | 1017. | 28.3 | 1028.04 | 1.09 | 18.90 | 36843.5 | 36965.3 | 192.3 |
| 1 | 2210. | 957. | 30.8 | 916.64 | -4.22 | 18.13 | 28459.1 | 30088.1 | 173.5 |
| 3 | 2387. | 1310. | 28.4 | 1354.27 | 3.38 | 13.41 | 28920.4 | 30880.4 | 175.7 |
| 5 | 2589. | 590. | 27.0 | 617.27 | 4.62 | 15.72 | 7853.8 | 8597.3 | 92.7 |
| 1 | 2602. | 737. | 30.8 | 729.15 | -1.06 | 17.71 | 16971.5 | 17033.1 | 130.5 |
| 3 | 2277. | 411. | 28.3 | 418.97 | 1.94 | 11.96 | 2351.7 | 2415.3 | 49.1 |
| 5 | 2284. | 1047. | 27.1 | 1033.80 | -1.26 | 14.53 | 22980.0 | 23154.1 | 152.2 |
| 3 | 2389. | 817. | 28.9 | 820.85 | 2.46 | 15.47 | 17994.1 | 18555.1 | 128.0 |

Appendix II, cont.

Species: Whitebelly spinner
Number of boats: 10
Percent coverage: 75%
Number of iterations: 50
Random seed number: 4565432

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 38 | 2473. | 356. | 28.5 | 351.16 | -1.36 | 17.25 | 3746.4 | 3769.8 | 61.4 |
| 40 | 2259. | 292. | 30.2 | 291.18 | -0.28 | 16.48 | 2315.2 | 2315.9 | 48.1 |
| 40 | 2572. | 234. | 30.0 | 231.00 | -1.28 | 17.11 | 1594.9 | 1603.9 | 40.0 |
| 38 | 2241. | 349. | 28.3 | 341.25 | -2.22 | 22.50 | 6106.1 | 6166.1 | 78.5 |
| 41 | 2210. | 442. | 30.8 | 451.55 | 2.16 | 19.56 | 7386.9 | 7478.1 | 86.5 |
| 38 | 2387. | 389. | 28.4 | 370.05 | -4.87 | 24.20 | 8503.5 | 8862.6 | 94.1 |
| 36 | 2589. | 189. | 27.0 | 188.11 | -0.47 | 12.46 | 554.2 | 555.0 | 23.6 |
| 41 | 2602. | 270. | 30.8 | 263.98 | -2.23 | 18.86 | 2556.3 | 2592.5 | 50.9 |
| 38 | 2277. | 203. | 28.3 | 202.94 | -0.03 | 23.44 | 2263.6 | 2263.6 | 47.6 |
| 36 | 2284. | 239. | 27.1 | 239.54 | 0.23 | 15.86 | 1436.2 | 1436.5 | 37.9 |
| 38 | 2389. | 296. | 28.9 | 293.08 | 1.51 | 18.77 | 3646.3 | 3704.4 | 56.9 |

Species: Common dolphin
Number of boats: 10
Percent coverage: 75%
Number of iterations: 50
Random seed number: 4565432

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 38 | 2473. | 76. | 28.5 | 81.48 | 7.21 | 38.57 | 829.2 | 859.3 | 29.3 |
| 40 | 2259. | 36. | 30.2 | 35.13 | -2.43 | 55.22 | 394.4 | 395.1 | 19.9 |
| 40 | 2572. | 766. | 30.0 | 781.00 | 1.96 | 41.66 | 101631.3 | 101856.2 | 319.1 |
| 38 | 2241. | 8. | 28.3 | 6.28 | -21.45 | 71.05 | 29.4 | 32.3 | 5.7 |
| 41 | 2210. | 69. | 30.8 | 66.14 | -4.15 | 48.32 | 1103.6 | 1111.7 | 33.3 |
| 38 | 2387. | 828. | 28.4 | 843.67 | 1.89 | 39.24 | 105292.7 | 105538.2 | 324.9 |
| 36 | 2589. | 781. | 27.0 | 798.27 | 2.21 | 41.11 | 102778.4 | 103076.6 | 321.1 |
| 41 | 2602. | 8. | 30.8 | 7.21 | -9.90 | 63.35 | 25.1 | 25.7 | 5.1 |
| 38 | 2277. | 770. | 28.3 | 875.84 | 13.74 | 35.33 | 62799.0 | 74000.3 | 272.0 |
| 36 | 2284. | 766. | 27.1 | 763.13 | -0.37 | 40.62 | 96826.1 | 96834.4 | 311.2 |
| 38 | 2389. | 411. | 28.9 | 425.81 | 6.53 | 47.45 | 47170.9 | 48373.0 | 164.2 |

endix II, cont.

cies: Total kill
ber of boats: 20
cent coverage: 25%
ber of iterations: 50
dom seed number: 9838749

| Population p Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|
| 4524. | 8752. | 17.9 | 9840.68 | 12.44 | 29.83 | 5629307.0 | 6814529.5 | 2610.5 |
| 4317. | 7741. | 18.8 | 7589.51 | -1.96 | 20.19 | 2419571.5 | 2442520.2 | 1562.9 |
| 4558. | 7485. | 17.8 | 7148.21 | -4.50 | 20.55 | 2252348.0 | 2365777.2 | 1538.1 |
| 4262. | 7412. | 17.9 | 7114.74 | -4.01 | 24.07 | 3094449.7 | 3182811.7 | 1784.0 |
| 4610. | 7315. | 19.5 | 7056.23 | -3.54 | 18.77 | 1818537.1 | 1885501.0 | 1373.1 |
| 4783. | 7875. | 18.4 | 7624.52 | -3.18 | 21.47 | 2794787.0 | 2857529.7 | 1690.4 |
| 4662. | 7997. | 19.2 | 7419.44 | -7.22 | 19.10 | 1999897.5 | 2333469.5 | 1527.6 |
| 4647. | 7800. | 19.5 | 7718.79 | -1.04 | 17.92 | 1946171.0 | 1952766.9 | 1397.4 |
| 4539. | 7741. | 18.5 | 7823.05 | 1.06 | 25.55 | 3904723.7 | 3911456.2 | 1977.7 |
| 4458. | 7927. | 18.5 | 7675.16 | -3.18 | 19.22 | 2258426.2 | 2321851.0 | 1523.8 |
| 4536. | 7804. | 18.6 | 7701.03 | 4.21 | 21.67 | 2811821.7 | 3006821.2 | 1698.6 |

ecies: Offshore spotted
ıber of boats: 20
rcent coverage: 25%
ıber of iterations: 50
ıdom seed number: 9838749

| Population p Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|
| 4524. | 5271. | 17.9 | 5912.00 | 12.16 | 34.03 | 2806475.5 | 3217355.5 | 1793.7 |
| 4317. | 4609. | 18.8 | 4312.20 | -6.44 | 18.60 | 647192.8 | 735284.0 | 857.5 |
| 4558. | 4744. | 17.8 | 4618.89 | -2.64 | 29.41 | 1930946.7 | 1946600.5 | 1395.2 |
| 4262. | 4818. | 17.9 | 4512.63 | -6.34 | 30.96 | 2132137.2 | 2225387.5 | 1491.8 |
| 4610. | 5429. | 19.5 | 5230.40 | -3.66 | 23.07 | 1529725.0 | 1569165.0 | 1252.7 |
| 4783. | 4804. | 18.4 | 4669.23 | -2.81 | 25.09 | 1435142.2 | 1453304.0 | 1205.5 |
| 4662. | 4645. | 19.2 | 4297.75 | -7.48 | 17.71 | 555961.5 | 676544.7 | 822.5 |
| 4647. | 4617. | 19.5 | 4551.67 | -1.42 | 22.92 | 1115979.0 | 1120247.1 | 1058.4 |
| 4539. | 4766. | 18.5 | 4657.39 | -2.28 | 27.94 | 1761218.5 | 1773015.4 | 1331.5 |
| 4458. | 4358. | 18.5 | 4217.80 | -3.22 | 20.31 | 763501.0 | 783157.7 | 885.0 |
| 4536. | 4806. | 18.6 | 4698.00 | 4.84 | 25.01 | 1467827.9 | 1550006.1 | 1209.4 |

Appendix II, cont.

Species: Eastern spinner
Number of boats: 20
Percent coverage: 25%
Number of iterations: 50
Random seed number: 9838749

| Trip | Population Day | Population Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 72 | 4524. | 1665. | 17.9 | 1583.67 | -4.88 | 29.29 | 231186.5 | 237801.7 | 487.6 |
| 76 | 4317. | 1350. | 18.8 | 1244.47 | -7.82 | 33.35 | 191573.7 | 202710.2 | 450.2 |
| 73 | 4558. | 1222. | 17.8 | 1213.09 | -0.73 | 32.73 | 159908.7 | 159988.1 | 400.0 |
| 71 | 4262. | 1575. | 17.9 | 1476.38 | -6.26 | 29.33 | 203602.1 | 213328.8 | 461.9 |
| 77 | 4610. | 1071. | 19.5 | 1074.09 | 0.29 | 35.99 | 148551.5 | 148561.0 | 385.4 |
| 74 | 4783. | 1398. | 18.4 | 1337.44 | -4.33 | 22.70 | 97024.8 | 100692.0 | 317.3 |
| 76 | 4662. | 1716. | 19.2 | 1615.13 | -5.88 | 29.97 | 254360.6 | 264535.5 | 514.3 |
| 77 | 4647. | 1701. | 19.5 | 1658.30 | -2.51 | 39.85 | 457730.6 | 459554.2 | 677.9 |
| 74 | 4539. | 1384. | 18.5 | 1447.92 | 4.62 | 38.16 | 274776.4 | 278862.5 | 528.1 |
| 74 | 4458. | 1777. | 18.5 | 1766.43 | -0.59 | 29.73 | 279033.3 | 279145.0 | 528.3 |
| 74 | 4536. | 1486. | 18.6 | 1441.69 | 3.79 | 32.11 | 229774.8 | 234517.9 | 475.1 |

Species: Whitebelly spinner
Number of boats: 20
Percent coverage: 25%
Number of iterations: 50
Random seed number: 9838749

| Trip | Population Day | Population Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 72 | 4524. | 526. | 17.9 | 594.15 | 12.96 | 45.99 | 53883.8 | 58527.8 | 241.9 |
| 76 | 4317. | 568. | 18.8 | 573.98 | 1.05 | 46.79 | 70589.4 | 70625.2 | 265.8 |
| 73 | 4558. | 539. | 17.8 | 510.50 | -5.29 | 37.73 | 40555.1 | 41367.3 | 203.4 |
| 71 | 4262. | 526. | 17.9 | 503.75 | -4.23 | 52.53 | 75850.1 | 76345.0 | 276.3 |
| 77 | 4610. | 566. | 19.5 | 502.15 | -11.28 | 37.03 | 39849.4 | 43925.6 | 209.6 |
| 74 | 4783. | 664. | 18.4 | 663.98 | 0.00 | 45.50 | 91273.7 | 91273.7 | 302.1 |
| 76 | 4662. | 397. | 19.2 | 364.89 | -8.09 | 43.91 | 29363.0 | 30394.2 | 174.3 |
| 77 | 4647. | 504. | 19.5 | 532.87 | 5.73 | 56.98 | 81633.3 | 82466.6 | 287.2 |
| 74 | 4539. | 545. | 18.5 | 539.75 | -0.96 | 42.47 | 53545.9 | 53573.5 | 231.5 |
| 74 | 4458. | 555. | 18.5 | 560.62 | 1.01 | 46.20 | 65700.6 | 65732.2 | 256.4 |
| 74 | 4536. | 539. | 18.6 | 534.66 | 5.06 | 45.51 | 60224.4 | 61423.1 | 244.8 |

cies: Common dolphin
ber of boats: 20
cent coverage: 25%
ber of iterations: 50
dom seed number: 9838749

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 4524. | 829. | 17.9 | 1350.55 | 62.91 | 147.91 | 1231592.6 | 1503602.6 | 1226.2 |
| 5 | 4317. | 778. | 18.8 | 974.95 | 25.31 | 139.59 | 1140607.2 | 1179396.6 | 1086.0 |
| 8 | 4558. | 867. | 17.8 | 705.75 | -18.60 | 102.35 | 761434.2 | 787435.4 | 887.4 |
| 1 | 4262. | 86. | 17.9 | 81.35 | -5.41 | 111.77 | 9218.2 | 9239.8 | 96.1 |
| 7 | 4610. | 110. | 19.5 | 119.55 | 8.68 | 94.64 | 10746.6 | 10837.9 | 104.1 |
| 4 | 4783. | 861. | 18.4 | 805.90 | -6.40 | 111.74 | 922516.9 | 925552.7 | 962.1 |
| 5 | 4662. | 819. | 19.2 | 680.19 | -16.95 | 106.01 | 734492.8 | 753760.2 | 868.2 |
| 7 | 4647. | 830. | 19.5 | 839.83 | 1.18 | 116.62 | 936746.7 | 936843.4 | 967.9 |
| 4 | 4539. | 878. | 18.5 | 1006.72 | 14.66 | 117.62 | 1049934.6 | 1066503.4 | 1032.7 |
| 4 | 4458. | 781. | 18.5 | 702.95 | -9.99 | 122.79 | 913609.0 | 919700.7 | 959.0 |
| 4 | 4536. | 684. | 18.6 | 726.77 | 17.01 | 117.10 | 771089.9 | 809287.2 | 819.0 |

ecies: Total kill
mber of boats: 20
rcent coverage: 50%
mber of iterations: 50
ndom seed number: 3947430

| ip | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 9 | 4563. | 8608. | 39.6 | 8525.82 | -0.95 | 11.53 | 977646.7 | 984400.8 | 992.2 |
| 7 | 4624. | 8100. | 38.5 | 8057.01 | -0.53 | 11.64 | 887814.2 | 889661.9 | 943.2 |
| 5 | 4518. | 7839. | 37.4 | 7980.09 | 1.80 | 13.26 | 1060835.7 | 1080743.0 | 1039.6 |
| 5 | 4709. | 7647. | 38.3 | 7479.69 | -2.19 | 13.21 | 991943.6 | 1019937.6 | 1009.9 |
| 5 | 4484. | 8377. | 38.0 | 8319.38 | -0.69 | 12.69 | 1127245.7 | 1130565.7 | 1063.3 |
| 4 | 4234. | 8163. | 37.6 | 8274.03 | 1.36 | 10.66 | 745240.9 | 757568.4 | 870.4 |
| 4 | 4499. | 7713. | 36.9 | 7751.17 | 0.49 | 10.96 | 713620.1 | 715077.4 | 845.6 |
| 2 | 4507. | 7876. | 36.2 | 7992.07 | 1.47 | 11.96 | 873488.5 | 886961.3 | 941.8 |
| 9 | 4313. | 7972. | 34.4 | 8021.47 | 0.62 | 14.75 | 1379753.9 | 1382201.5 | 1175.7 |
| 0 | 4799. | 9621. | 40.2 | 9580.51 | -0.42 | 11.16 | 1152055.7 | 1153695.4 | 1074.1 |
| 5 | 4525. | 8192. | 37.7 | 8198.12 | 1.05 | 12.18 | 990964.5 | 1000081.3 | 995.6 |

Appendix II, cont.

Species: Offshore spotted
Number of boats: 20
Percent coverage: 50%
Number of iterations: 50
Random seed number: 3947430

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 79 | 4563. | 5191. | 39.6 | 5257.52 | 1.28 | 13.04 | 453695.8 | 458120.3 | 676.8 |
| 77 | 4624. | 5058. | 38.5 | 5030.32 | -0.55 | 11.91 | 362339.1 | 363105.2 | 602.6 |
| 75 | 4518. | 4716. | 37.4 | 4844.93 | 2.73 | 14.38 | 443559.3 | 460181.7 | 678.4 |
| 76 | 4709. | 5071. | 38.3 | 4975.22 | -1.89 | 15.67 | 621901.4 | 631074.6 | 794.4 |
| 76 | 4484. | 5257. | 38.0 | 5189.90 | -1.28 | 13.25 | 480474.4 | 484976.7 | 696.4 |
| 74 | 4234. | 5655. | 37.6 | 5713.66 | 1.04 | 11.20 | 397705.2 | 401146.0 | 633.4 |
| 74 | 4499. | 4984. | 36.9 | 5002.91 | 0.38 | 11.50 | 328413.9 | 328771.5 | 573.4 |
| 72 | 4507. | 4499. | 36.2 | 4508.74 | 0.22 | 16.37 | 542124.0 | 542218.9 | 736.4 |
| 69 | 4313. | 4629. | 34.4 | 4639.33 | 0.22 | 16.55 | 587121.3 | 587227.9 | 766.3 |
| 80 | 4799. | 5847. | 40.2 | 5810.04 | -0.63 | 14.07 | 675695.6 | 677061.6 | 822.8 |
| 75 | 4525. | 5091. | 37.7 | 5097.26 | 1.02 | 13.79 | 489303.0 | 493388.4 | 698.1 |

Species: Eastern spinner
Number of boats: 20
Percent coverage: 50%
Number of iterations: 50
Random seed number: 3947430

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 79 | 4563. | 1573. | 39.6 | 1587.00 | 0.89 | 19.04 | 89456.7 | 89652.8 | 299.4 |
| 77 | 4624. | 1377. | 38.5 | 1385.74 | 0.63 | 19.32 | 70704.0 | 70780.5 | 266.0 |
| 75 | 4518. | 1370. | 37.4 | 1467.89 | 7.15 | 25.96 | 116881.9 | 126464.8 | 355.6 |
| 76 | 4709. | 1635. | 38.3 | 1611.37 | -1.45 | 18.61 | 92004.3 | 92562.8 | 304.2 |
| 76 | 4484. | 1340. | 38.0 | 1341.27 | 0.09 | 21.72 | 84735.6 | 84737.2 | 291.1 |
| 74 | 4234. | 1393. | 37.6 | 1409.31 | 1.17 | 22.88 | 101324.4 | 101590.3 | 318.7 |
| 74 | 4499. | 1618. | 36.9 | 1616.38 | -0.10 | 18.56 | 90154.7 | 90157.3 | 300.3 |
| 72 | 4507. | 1616. | 36.2 | 1635.78 | 1.22 | 18.31 | 87174.7 | 87565.8 | 295.9 |
| 69 | 4313. | 1568. | 34.4 | 1614.65 | 2.98 | 20.37 | 99790.8 | 101967.4 | 319.3 |
| 80 | 4799. | 1880. | 40.2 | 1924.97 | 2.39 | 17.17 | 102121.5 | 104143.9 | 322.7 |
| 75 | 4525. | 1537. | 37.7 | 1559.44 | 1.81 | 20.19 | 93434.9 | 94962.3 | 307.3 |

endix II, cont.

cies: Whitebelly spinner
ber of boats: 20
cent coverage: 50%
ber of iterations: 50
dom seed number: 3947430

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| ) | 4563. | 522. | 39.6 | 531.65 | 1.85 | 23.10 | 14449.9 | 14543.1 | 120.6 |
| ' | 4624. | 714. | 38.5 | 704.73 | -1.30 | 25.00 | 31771.3 | 31857.2 | 178.5 |
| ; | 4518. | 550. | 37.4 | 543.13 | -1.25 | 27.66 | 23094.1 | 23141.3 | 152.1 |
| ; | 4709. | 411. | 38.3 | 405.59 | -1.32 | 25.16 | 10661.4 | 10690.6 | 103.4 |
| 5 | 4484. | 588. | 38.0 | 570.40 | -2.99 | 23.80 | 19278.7 | 19588.4 | 140.0 |
| 4 | 4234. | 646. | 37.6 | 665.56 | 3.03 | 18.53 | 13945.9 | 14328.6 | 119.7 |
| 4 | 4499. | 611. | 36.9 | 632.44 | 3.51 | 23.09 | 19447.3 | 19906.8 | 141.1 |
| 2 | 4507. | 466. | 36.2 | 477.39 | 2.44 | 27.08 | 15791.2 | 15920.9 | 126.2 |
| 9 | 4313. | 540. | 34.4 | 554.99 | 2.78 | 26.18 | 19763.8 | 19988.4 | 141.4 |
| ) | 4799. | 561. | 40.2 | 561.83 | 0.15 | 27.11 | 23136.4 | 23137.1 | 152.1 |
| 5 | 4525. | 561. | 37.7 | 564.77 | 2.06 | 24.67 | 19134.0 | 19310.2 | 137.5 |

ecies: Common dolphin
nber of boats: 20
rcent coverage: 50%
nber of iterations: 50
ndom seed number: 3947430

| ip | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 9 | 4563. | 842. | 39.6 | 696.07 | -17.33 | 64.19 | 270832.7 | 292129.7 | 540.5 |
| 7 | 4624. | 791. | 38.5 | 769.78 | -2.68 | 69.69 | 303464.5 | 303914.9 | 551.3 |
| 5 | 4518. | 814. | 37.4 | 722.89 | -11.19 | 67.32 | 291990.2 | 300291.2 | 548.0 |
| 6 | 4709. | 100. | 38.3 | 93.69 | -6.31 | 69.65 | 4810.7 | 4850.5 | 69.6 |
| 6 | 4484. | 772. | 38.0 | 800.48 | 3.69 | 70.18 | 292725.8 | 293537.2 | 541.8 |
| 4 | 4234. | 50. | 37.6 | 51.60 | 3.21 | 71.26 | 1267.1 | 1269.7 | 35.6 |
| 4 | 4499. | 25. | 36.9 | 25.54 | 2.18 | 50.35 | 158.1 | 158.4 | 12.6 |
| 2 | 4507. | 882. | 36.2 | 953.68 | 8.13 | 64.03 | 313785.7 | 318923.4 | 564.7 |
| 9 | 4313. | 853. | 34.4 | 811.21 | -4.90 | 63.61 | 292673.3 | 294419.5 | 542.6 |
| 0 | 4799. | 834. | 40.2 | 824.19 | -1.18 | 68.65 | 327666.6 | 327762.8 | 572.5 |
| 5 | 4525. | 596. | 37.7 | 574.91 | 6.08 | 65.89 | 209937.5 | 213725.7 | 397.9 |

Appendix II, cont.

Species: Total kill
Number of boats: 20
Percent coverage: 75%
Number of iterations: 50
Random seed number: 9384805

| Trip | Population Day | Population Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 75 | 4715. | 8697. | 56.2 | 8698.17 | 0.01 | 7.43 | 417278.6 | 417280.0 | 646.0 |
| 70 | 4455. | 7071. | 52.9 | 7094.02 | 0.33 | 6.26 | 195391.6 | 195921.3 | 442.6 |
| 75 | 4603. | 8412. | 56.2 | 8337.53 | -0.89 | 7.87 | 433166.2 | 438712.7 | 662.4 |
| 72 | 4458. | 8352. | 54.1 | 8298.04 | -0.65 | 6.55 | 296285.2 | 299196.9 | 547.0 |
| 75 | 4397. | 8536. | 56.4 | 8701.26 | 1.94 | 7.28 | 359040.8 | 386353.2 | 621.6 |
| 74 | 4383. | 7625. | 55.5 | 7544.83 | -1.05 | 6.83 | 265072.9 | 271500.1 | 521.1 |
| 79 | 5012. | 8931. | 59.1 | 8942.08 | 0.12 | 6.09 | 295865.8 | 295988.5 | 544.0 |
| 78 | 4779. | 8235. | 58.8 | 8110.62 | -1.51 | 7.68 | 384540.8 | 400011.1 | 632.5 |
| 74 | 4587. | 8623. | 55.5 | 8720.53 | 1.13 | 6.82 | 336420.0 | 345931.8 | 588.2 |
| 79 | 4656. | 7705. | 59.3 | 7792.21 | 1.13 | 7.02 | 284599.9 | 292205.9 | 540.6 |
| 75 | 4604. | 8219. | 56.4 | 8223.93 | 0.88 | 6.98 | 326766.2 | 334310.2 | 574.6 |

Species: Offshore spotted
Number of boats: 20
Percent coverage: 75%
Number of iterations: 50
Random seed number: 9384805

| Trip | Population Day | Population Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 75 | 4715. | 5217. | 56.2 | 5141.42 | -1.45 | 9.52 | 241112.2 | 246824.3 | 496.8 |
| 70 | 4455. | 3999. | 52.9 | 3962.41 | -0.91 | 6.08 | 57714.2 | 59053.1 | 243.0 |
| 75 | 4603. | 5615. | 56.2 | 5582.62 | -0.58 | 9.52 | 284741.2 | 285789.7 | 534.6 |
| 72 | 4458. | 4920. | 54.1 | 4906.10 | -0.28 | 7.87 | 149625.4 | 149818.5 | 387.1 |
| 75 | 4397. | 5508. | 56.4 | 5629.06 | 2.20 | 9.15 | 239271.5 | 253926.7 | 503.9 |
| 74 | 4383. | 5428. | 55.5 | 5363.11 | -1.20 | 7.65 | 168409.9 | 172621.2 | 415.5 |
| 79 | 5012. | 5524. | 59.1 | 5533.21 | 0.17 | 6.13 | 114420.3 | 114505.1 | 338.4 |
| 78 | 4779. | 4684. | 58.8 | 4636.52 | -1.01 | 8.51 | 156720.6 | 158975.2 | 398.7 |
| 74 | 4587. | 4955. | 55.5 | 5104.73 | 3.02 | 7.88 | 130087.7 | 152507.8 | 390.5 |
| 79 | 4656. | 5289. | 59.3 | 5379.50 | 1.71 | 8.62 | 199765.7 | 207956.8 | 456.0 |
| 75 | 4604. | 5114. | 56.4 | 5123.87 | 1.25 | 8.09 | 174186.9 | 180197.9 | 416.5 |

endix II, cont.

cies: Eastern spinner
ber of boats: 20
cent coverage: 75%
ber of iterations: 50
dom seed number: 9384805

| p | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 4715. | 1735. | 56.2 | 1754.43 | 1.12 | 10.30 | 31539.8 | 31917.3 | 178.7 |
| ) | 4455. | 1593. | 52.9 | 1639.26 | 2.90 | 11.20 | 29715.5 | 31855.9 | 178.5 |
| 5 | 4603. | 1695. | 56.2 | 1686.04 | -0.53 | 10.02 | 28772.4 | 28852.6 | 169.9 |
| ? | 4458. | 1477. | 54.1 | 1462.24 | -1.00 | 9.10 | 17849.3 | 18067.1 | 134.4 |
| 5 | 4397. | 1753. | 56.4 | 1731.90 | -1.20 | 11.87 | 42870.6 | 43315.6 | 208.1 |
| 1 | 4383. | 1360. | 55.5 | 1357.10 | -0.21 | 9.93 | 18213.7 | 18222.1 | 135.0 |
| ) | 5012. | 1837. | 59.1 | 1868.57 | 1.72 | 11.21 | 41432.2 | 42428.8 | 206.0 |
| 3 | 4779. | 1763. | 58.8 | 1776.87 | 0.79 | 9.62 | 28556.6 | 28748.9 | 169.6 |
| 1 | 4587. | 1830. | 55.5 | 1841.76 | 0.64 | 9.64 | 30976.9 | 31115.2 | 176.4 |
| ) | 4656. | 1445. | 59.3 | 1440.03 | -0.34 | 8.77 | 16018.0 | 16042.6 | 126.7 |
| 5 | 4604. | 1649. | 56.4 | 1655.82 | 1.05 | 10.17 | 28594.5 | 29056.6 | 168.3 |

ecies: Whitebelly spinner
mber of boats: 20
rcent coverage: 75%
mber of iterations: 50
ndom seed number: 9384805

| ip | Population Day | Kill | Samp Size | Mean Kill (Ŷ) | Rel-bias *100% | C.V. *100% | Variance (Ŷ) | MSE (Ŷ) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 4715. | 678. | 56.2 | 655.89 | -3.26 | 14.80 | 9573.3 | 10062.2 | 100.3 |
| 0 | 4455. | 569. | 52.9 | 538.55 | -5.35 | 16.21 | 7577.9 | 8505.3 | 92.2 |
| 5 | 4603. | 594. | 56.2 | 600.32 | 1.06 | 14.23 | 7108.2 | 7148.2 | 84.5 |
| 2 | 4458. | 665. | 54.1 | 664.34 | -0.10 | 13.76 | 8367.6 | 8368.1 | 91.5 |
| 5 | 4397. | 718. | 56.4 | 742.96 | 3.48 | 14.94 | 10887.1 | 11510.1 | 107.3 |
| 4 | 4383. | 661. | 55.5 | 651.15 | -1.49 | 13.01 | 7296.5 | 7393.5 | 86.0 |
| 9 | 5012. | 558. | 59.1 | 551.09 | -1.24 | 13.39 | 5535.5 | 5583.2 | 74.7 |
| 8 | 4779. | 538. | 58.8 | 516.88 | -3.93 | 17.43 | 8349.9 | 8796.0 | 93.8 |
| 4 | 4587. | 565. | 55.5 | 563.50 | -0.26 | 14.09 | 6334.5 | 6336.7 | 79.6 |
| 9 | 4656. | 691. | 59.3 | 700.14 | 1.32 | 15.37 | 11199.0 | 11282.6 | 106.2 |
| 5 | 4604. | 624. | 56.4 | 618.48 | 2.15 | 14.72 | 8222.9 | 8498.6 | 91.6 |

Appendix II, cont.

Species: Common dolphin
Number of boats: 20
Percent coverage: 75%
Number of iterations: 50
Random seed number: 9384805

| Trip | Population Day | Kill | Samp Size | Mean Kill ($\hat{Y}$) | Rel-bias *100% | C.V. *100% | Variance ($\hat{Y}$) | MSE ($\hat{Y}$) | SQRT (MSE) |
|---|---|---|---|---|---|---|---|---|---|
| 75 | 4715. | 874. | 56.2 | 950.37 | 8.74 | 33.61 | 80457.2 | 86289.7 | 293.8 |
| 70 | 4455. | 787. | 52.9 | 826.39 | 5.01 | 38.36 | 89571.6 | 91123.5 | 301.9 |
| 75 | 4603. | 93. | 56.2 | 87.71 | -5.69 | 40.54 | 1393.7 | 1421.7 | 37.7 |
| 72 | 4458. | 827. | 54.1 | 800.58 | -3.20 | 41.41 | 116569.1 | 117267.3 | 342.4 |
| 75 | 4397. | 86. | 56.4 | 85.62 | -0.45 | 39.23 | 1137.9 | 1138.0 | 33.7 |
| 74 | 4383. | 42. | 55.5 | 42.02 | 0.04 | 45.97 | 372.8 | 372.8 | 19.3 |
| 79 | 5012. | 819. | 59.1 | 793.94 | -3.06 | 39.85 | 105868.2 | 106496.2 | 326.3 |
| 78 | 4779. | 774. | 58.8 | 713.26 | -7.85 | 44.60 | 115463.6 | 119153.5 | 345.2 |
| 74 | 4587. | 817. | 55.5 | 763.56 | -6.54 | 41.76 | 113556.6 | 116412.6 | 341.2 |
| 79 | 4656. | 118. | 59.3 | 114.18 | -3.24 | 31.27 | 1346.5 | 1361.1 | 36.9 |
| 75 | 4604. | 524. | 56.4 | 517.76 | 4.38 | 39.66 | 62573.7 | 64103.7 | 207.8 |